A Prototype Diamond Detector for the Compton Polarimeter in Jefferson lab, Hall C

Medium Energy Physics Group
http://ra.msstate.edu/~dd285/mep.html

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Qweak

Jefferson Lab
Exploring the Nature of Matter

Outline

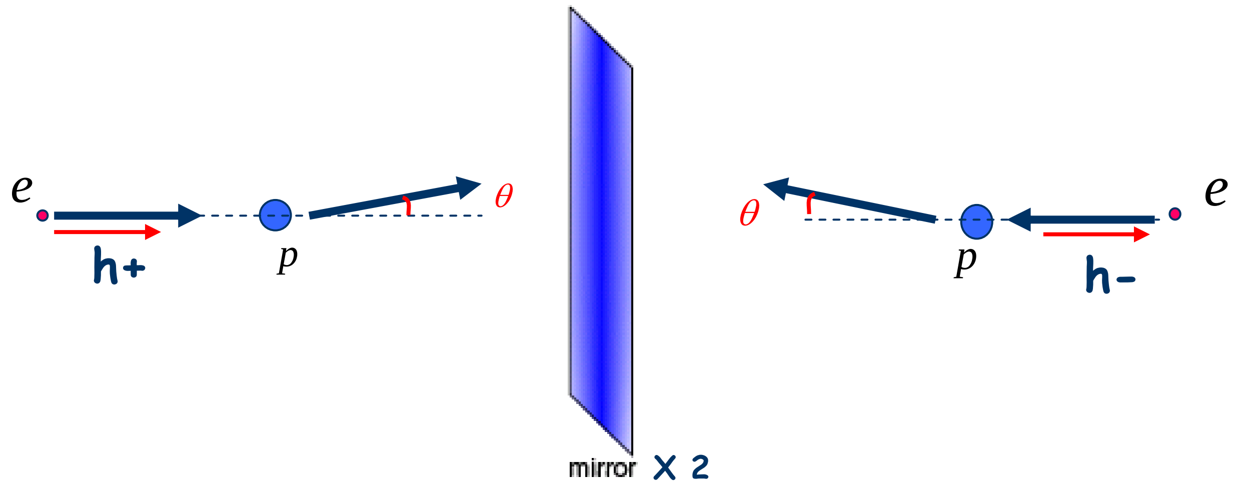
- ✓ PVES Program at Jlab, Hall C
- ✓ The Q_{Weak} Experiment
  - › Compton Polarimeter
  - › Electron Detector
- ✓ Electronic Setup
- ✓ Preliminary Results
- ✓ Future Tasks

Thanks: several slides adapted from talks by Dr.D.Dutta and Dr.R.D.Carlini

Parity Violating Electron Scattering (PVES)

The PVES program in Jefferson Lab, Hall-C includes high precision experiments such as the Qweak experiment and the 12 GeV Moller Experiment.

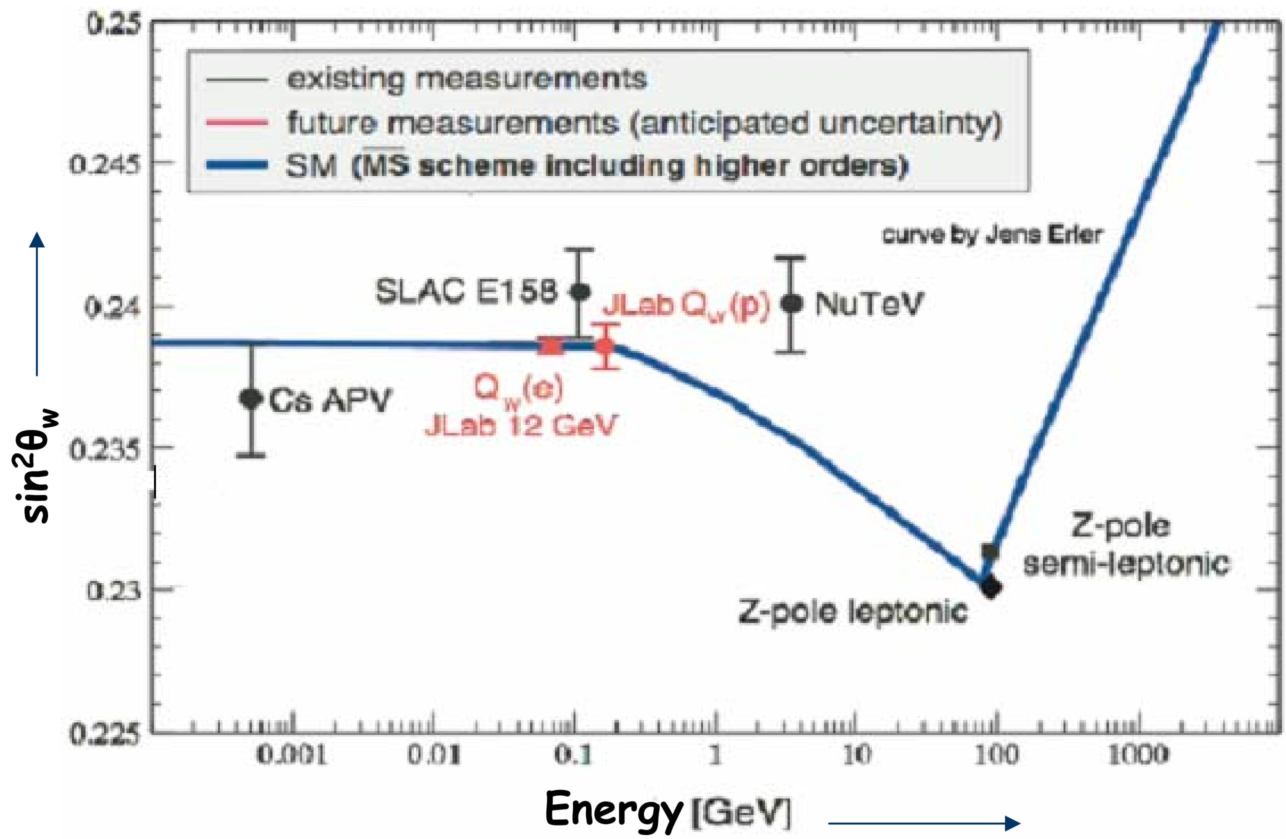
This entire program will rely on the accurate measurement of the polarization of the incident electron beam.



X 2
(parity transformation)

Example: The Qweak experiment aims to measure the weak charge of a proton with a precision of ~ 4%. This would need a 1% determination of the electron beam polarization.

The Qweak Experiment

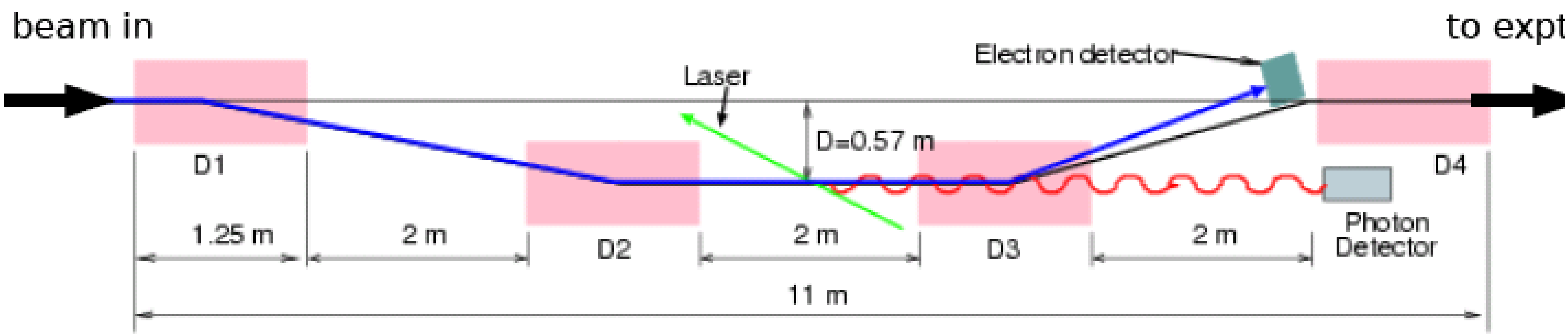


The Qweak experiment aims to measure the weak charge of the proton with a precision of ~4% which needs a 1% determination of the electron beam polarization.

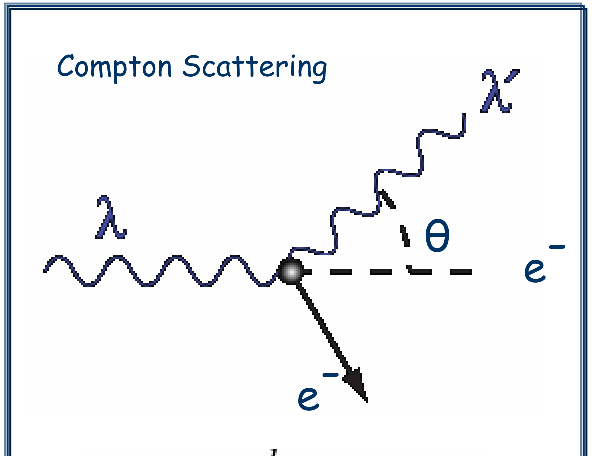
Thanks Dr.Roger Carlini, Principal Investigator, Q^pWeak Experiment @Jlab

The Compton Polarimeter

A high precision Compton Polarimeter is being constructed in Hall-C for a non-destructive continuous monitoring of the e^- beam polarization during the Qweak experiment and all other polarized e^- scattering experiments to follow after the upgrade of Jlab to 12 GeV capacity.



Parameter	Symbol	Value
Beam Energy	E_{beam}	1.165 GeV
Laser wavelength	λ	532 nm
Chicane bend angle	θ_{bend}	10 deg
Electron free drift distance	d_{drift}	3.3 m
Electron displacement at	X_{max}	23 mm



$$\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

Diamond: A Closer look ...

Silicon is a typical choice for a multi-strip position sensitive electron detector

Property	Silicon	Diamond
Band Gap (eV)	1.12	5.45
Electron/Hole mobility (cm^2/Vs)	1450/500	2200/1600
Saturation velocity (cm/s)	0.8×10^7	2×10^7
Breakdown field (V/m)	3×10^5	2.2×10^7
Dielectric Constant	11.9	5.7
Displacement energy (eV)	13-20	43
e-h creation energy (eV)	3.6	13
Av. e-h pairs per MIP per micron	89	36
Charge collection distance (micron)	full	~250

Low leakage current, short noise

Fast signal collection

Low capacitance, noise

Radiation hardness

Smaller signal

Advantages: lower leakage current, faster, lower noise and rad. hard

Disadvantages: smaller signal ~ 40% smaller

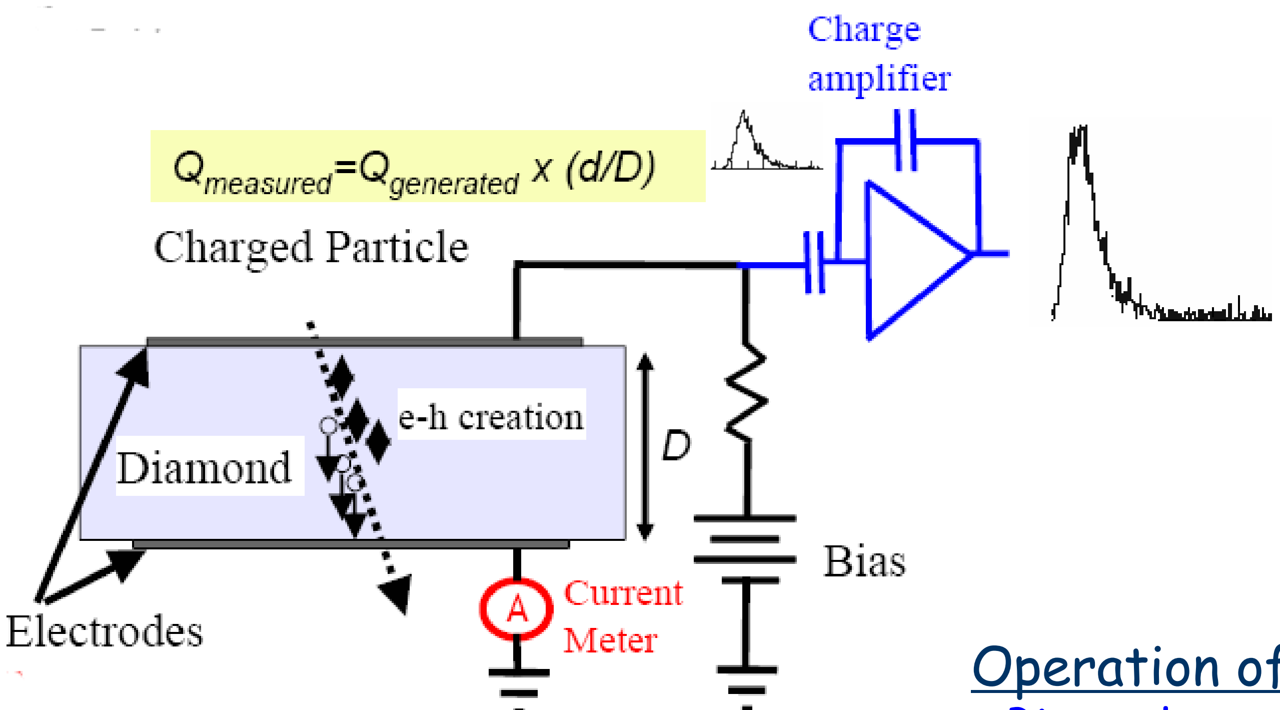
Recall that the Compton edge is 2cm from beam for recoil e^-

Thanks: Dr. R. Wallny (UCLA)

The Diamond Detector

- Diamond is known for its radiation hardness
- We chose Diamond (artificially grown by Chemical Vapor Deposition) for the detector

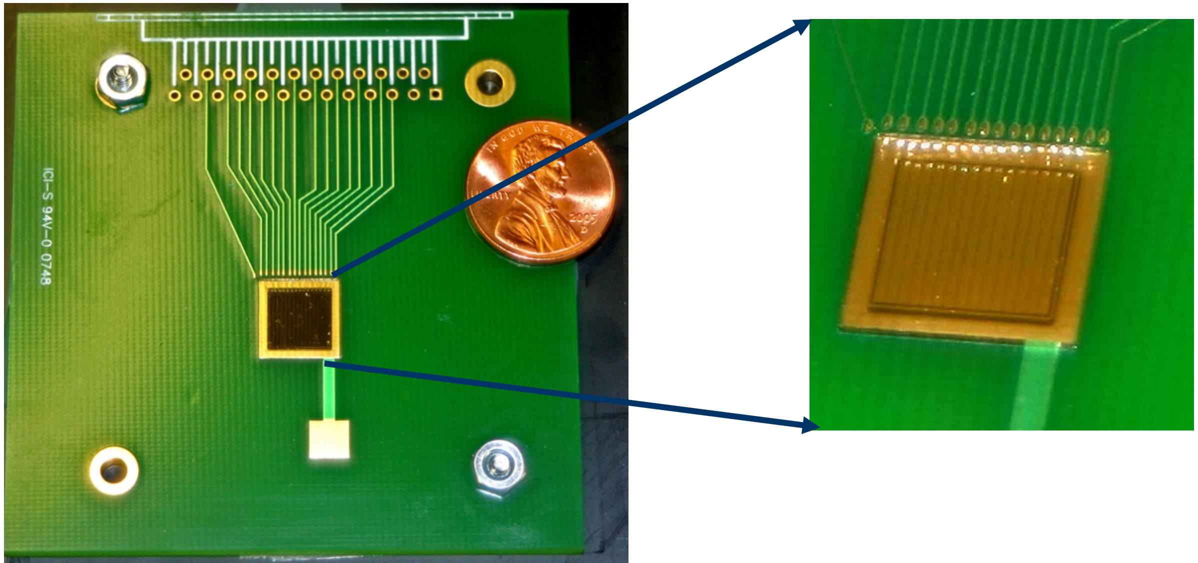
How does it work?



Operation of Diamond Detectors

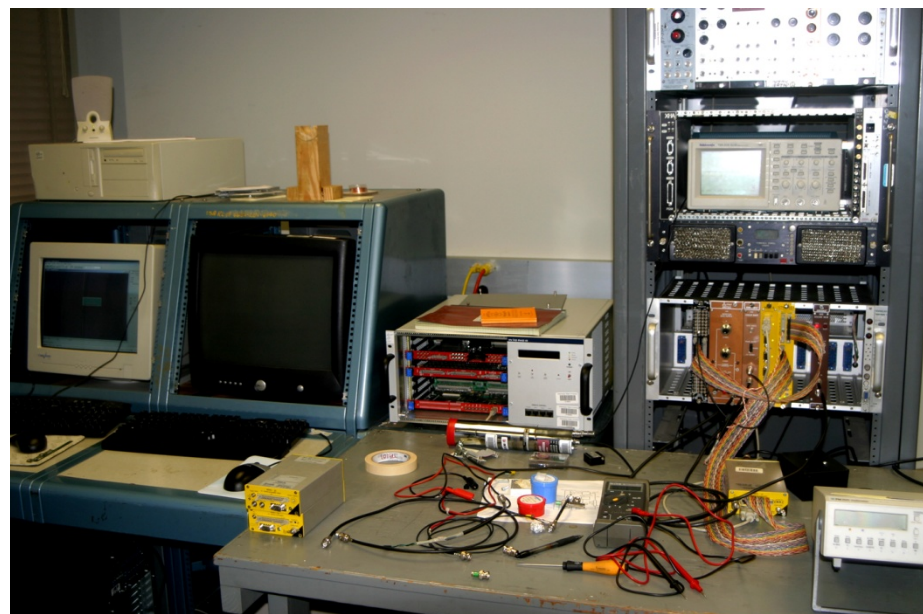
- Bias voltage ~ 1000 V,
- Charge collection distance ~ 250μ

A Prototype Diamond Detector

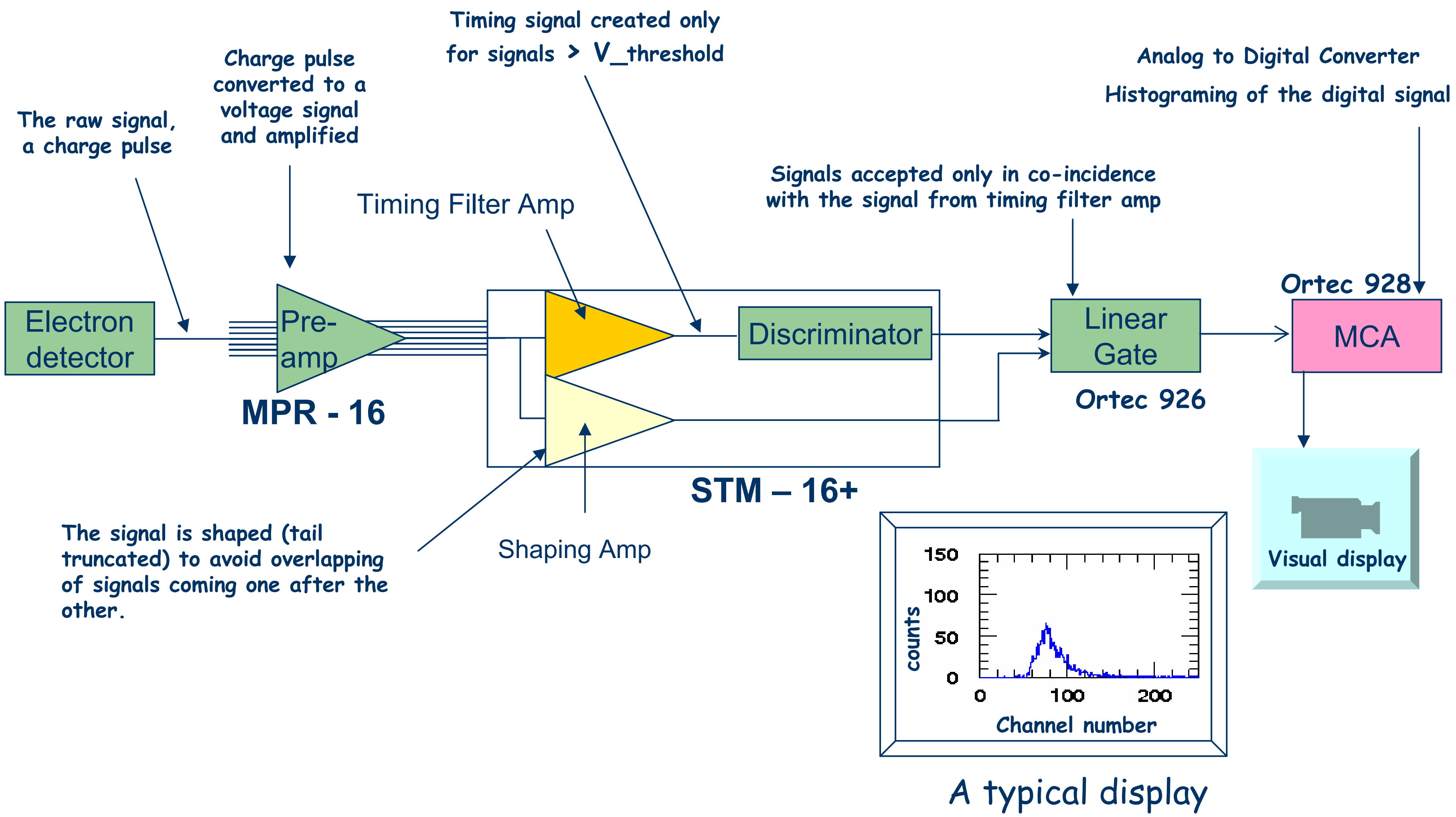


- 10×10 mm^2
- 500 μm thick
- 15 strips ~450 μm wide

Metallization, Lithography & wire bonding done in High Energy Physics Lab at Ohio State University. Thanks Prof. Harris Kagan and his group at OSU.

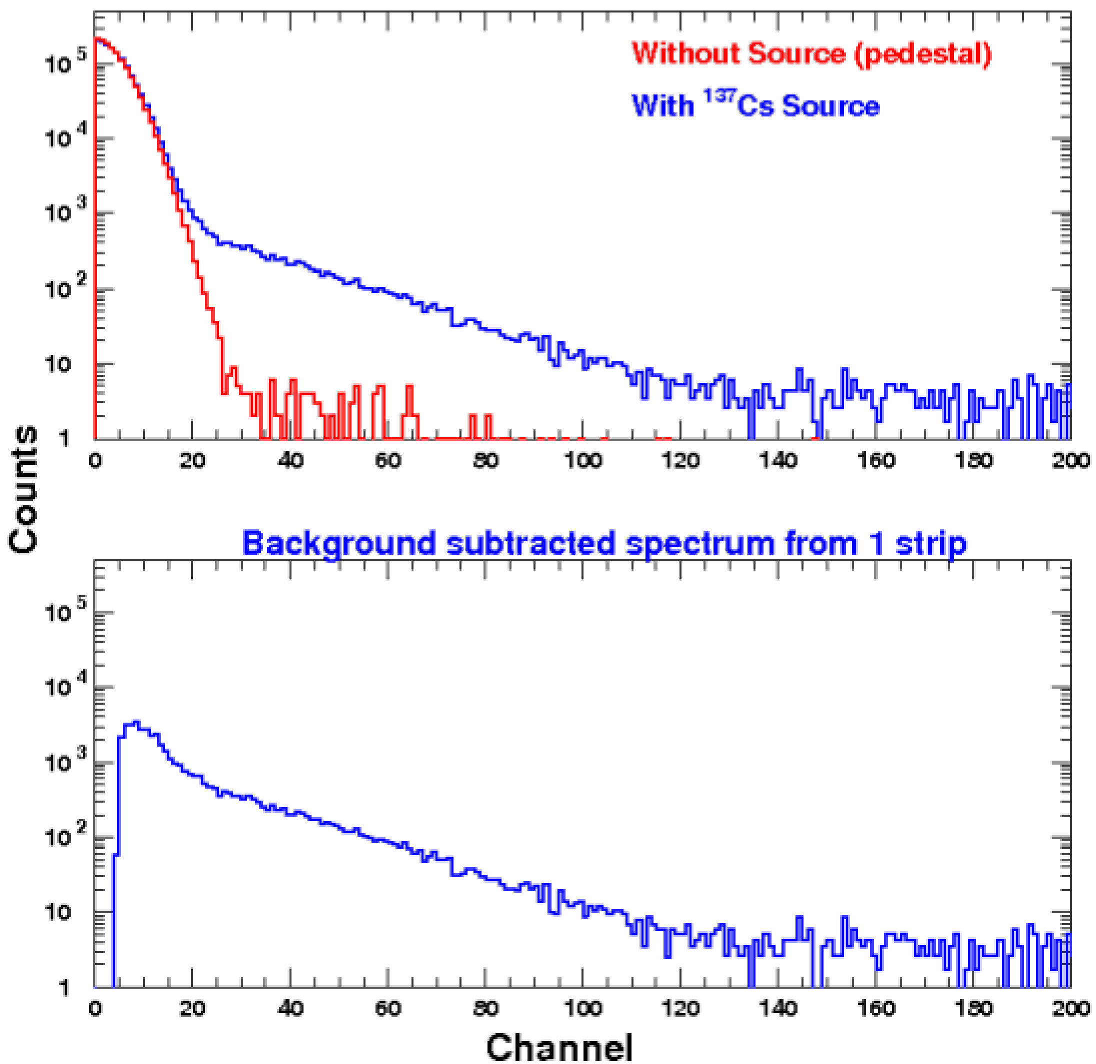


Schematic of the Electronic Setup



Spectrum obtained by the Diamond detector

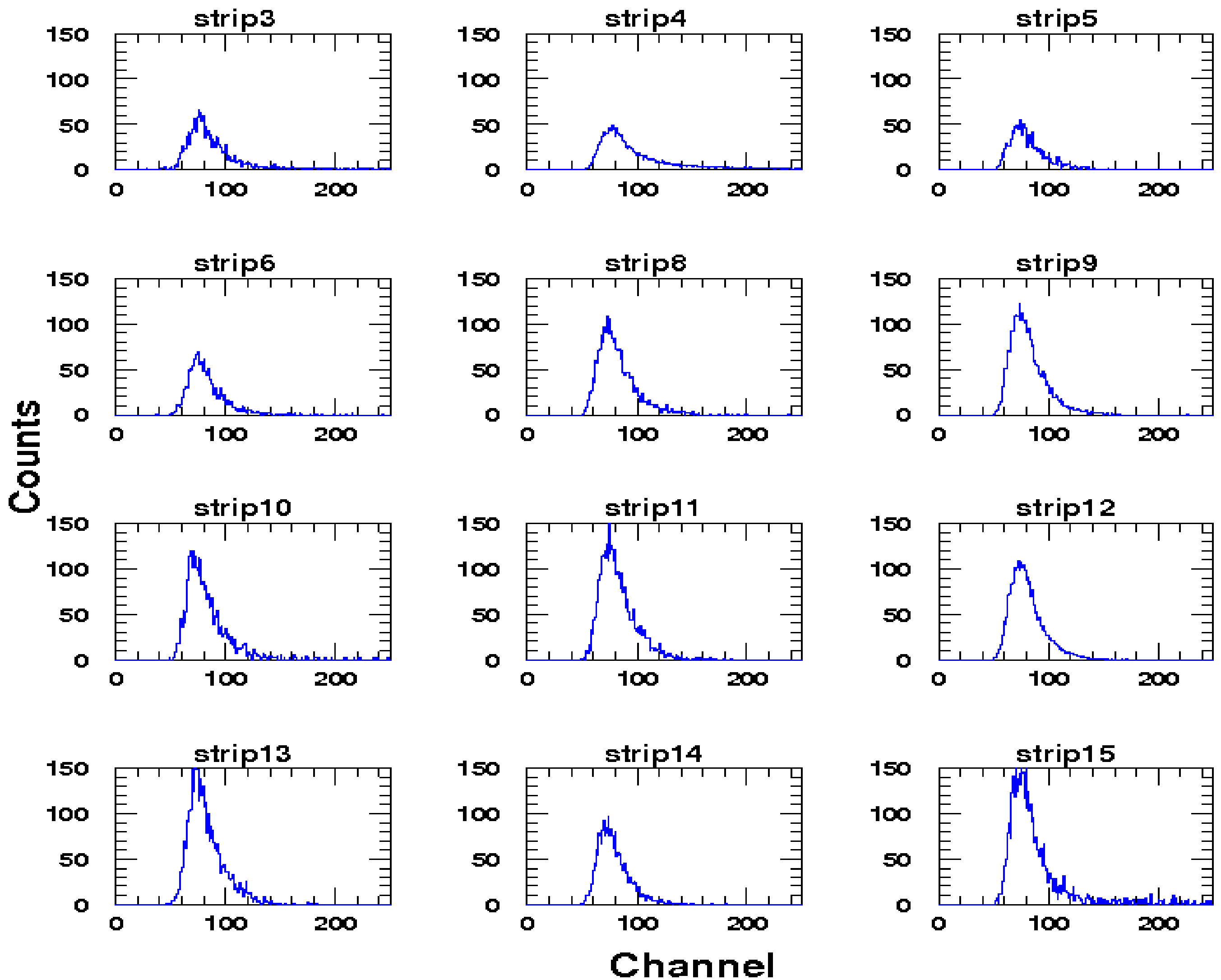
Threshold Voltage was low ~50 mV



Shaping Amplifier @20 gain

pedestal suppressed spectra from diamond

threshold set to 150 mV to suppress the background



Beta Particle Emission in Cs 137

A Silicon Detector with a Cs 137 Source was used to Calibrate the Multi-channel Analyzer in order to obtain the number of e-h pairs produced per MIP/µm in the detector.

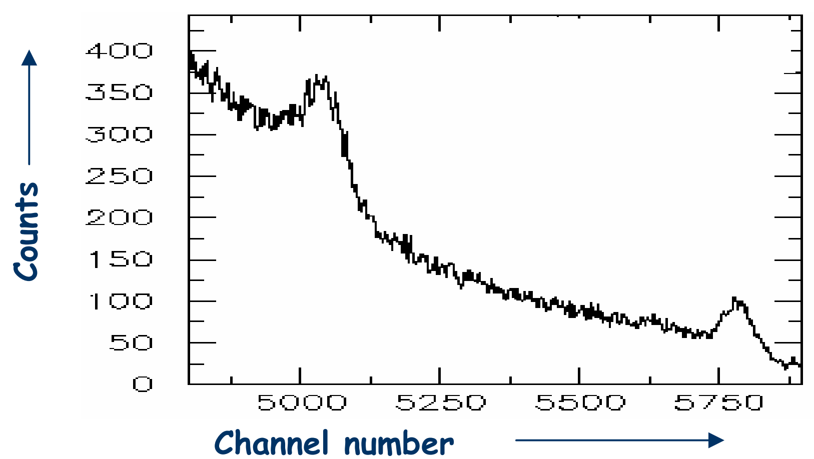
$$_{55}Cs^{137} \xrightarrow{\text{decays to}} {}_{56}Ba^{137} + {}_{-1}e$$

Mean energy of emitted electrons : 174.3 keV
End Point Energy of the electrons : 513.9 keV

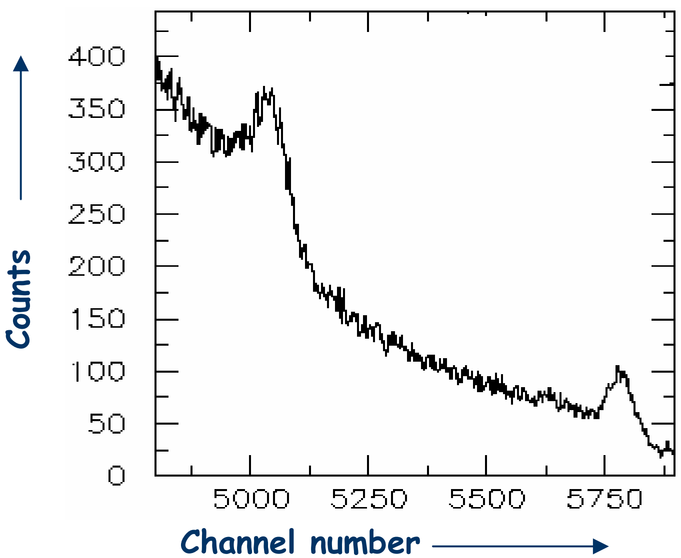
The Si detector being used has

- Surface Area: 50mm^2
- Thickness: 300 μm
- Voltage bias: 50 V

Two internal conversion electron peaks at 624 keV and 655 keV which are used to calibrate the MCA.



Conversion electron peaks of Cs137



THE FULL SPECTRUM

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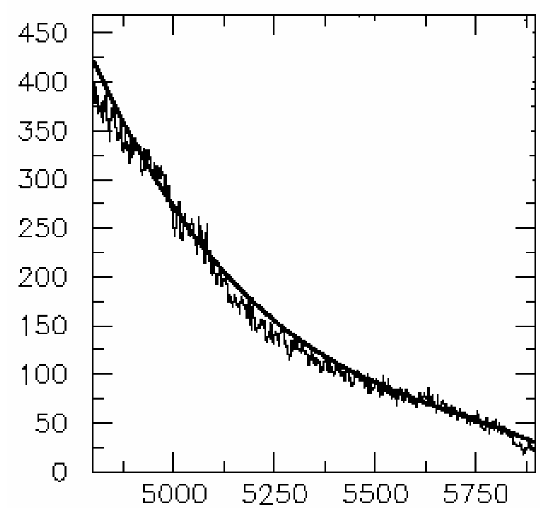
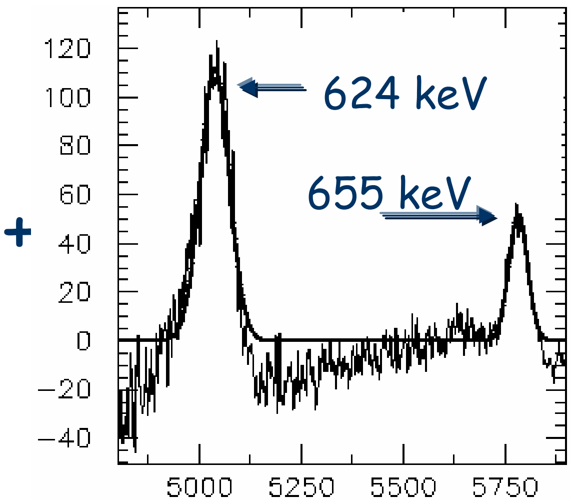


BACKGROUND

+

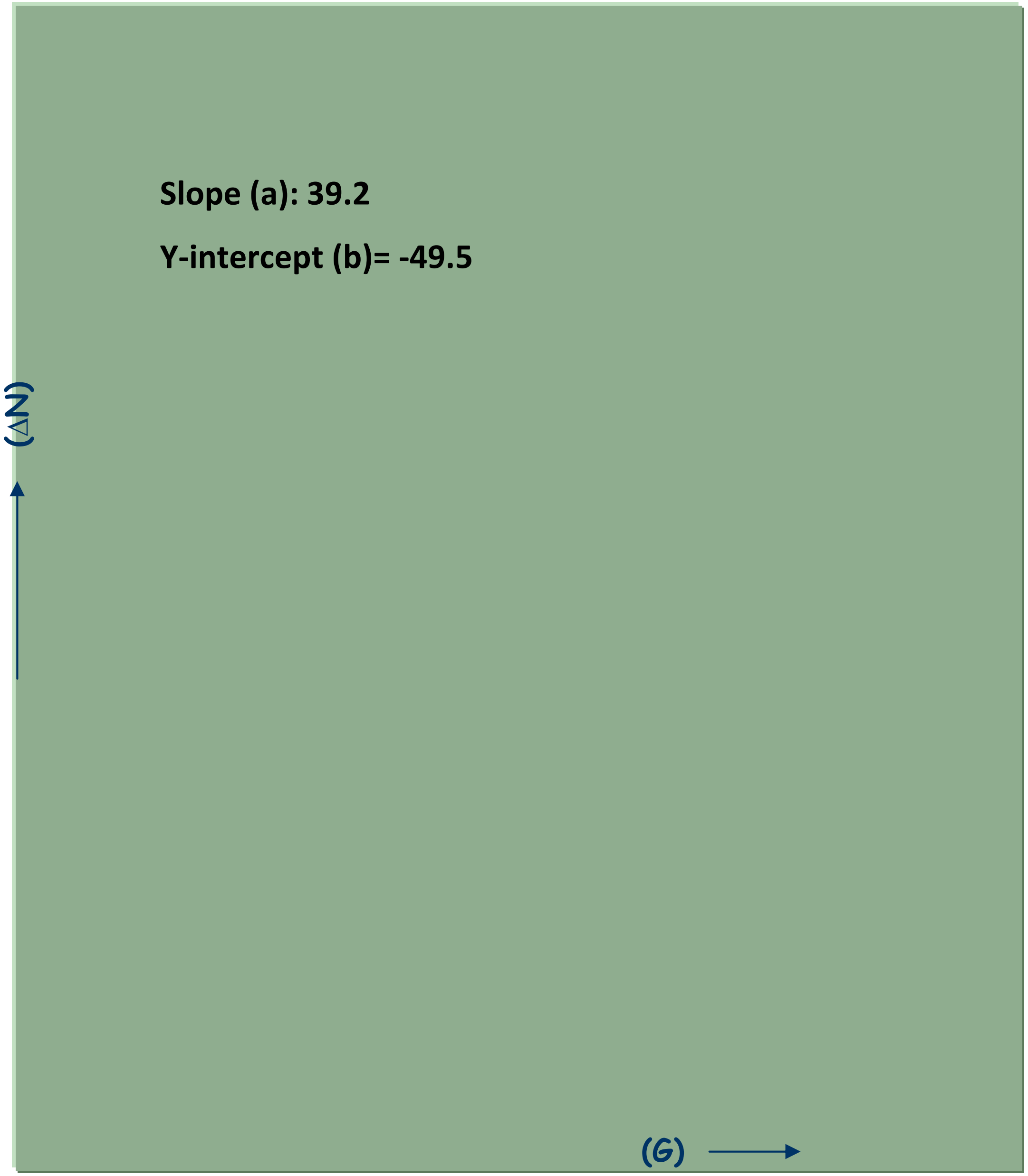


THE PEAKS

20 gain, 100 hour spectrum

The peaks are fit to a Gaussian to determine the peak position and sigma in order to obtain a calibration constant.

Calibration Curve for the MCB



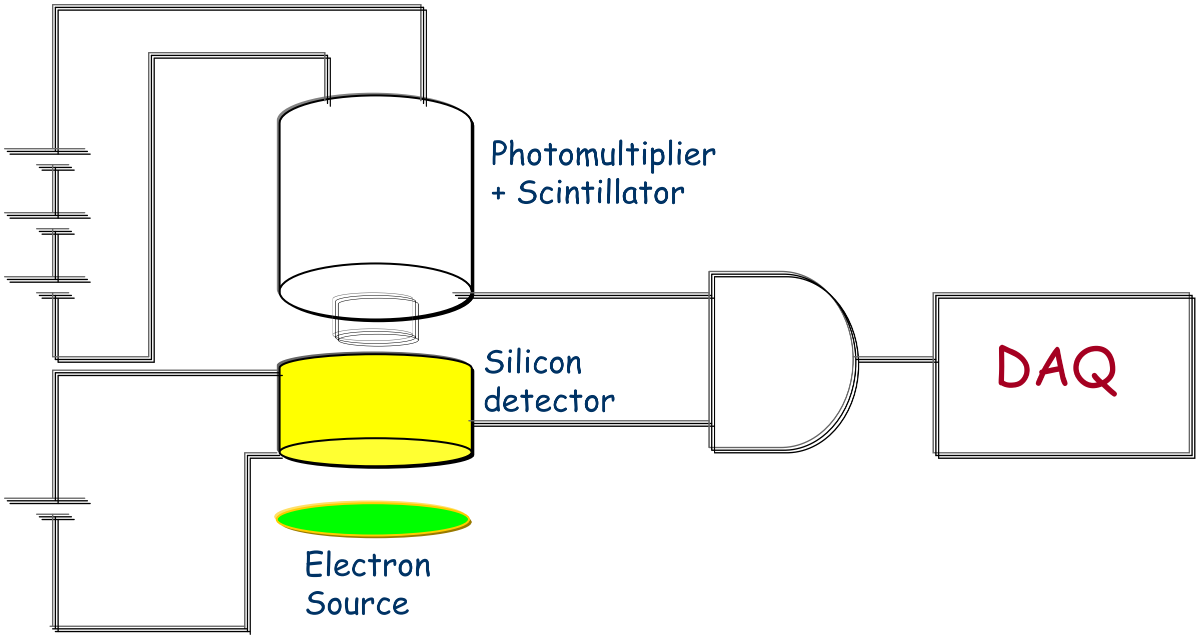
$\Delta N\ (\Delta E) = a\ G + b$

G = Gain of the Amplifier

ΔN = difference in Channel #

This calibration curve will be used to find the no. of electrons per MIP/μm for Si and compare that with Diamond.

Triggering with a Scintillator



Only those beta particles would be detected which pass the detector and reach the Scintillator.

Measuring only the minimum ionizing particles.

Next Steps

- Measure all 15 strips simultaneously
- Repeat the measurements in a real electron beam

  &

- Build the full size Diamond Detector

(4 planes, 21 x 21 mm^2, 200μm pitch)

Mississippi State Univ.,
Univ. of Winnipeg,
Univ. of Manitoba,
TRIUMF

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QUESTIONS !