Compton Polarimeter Electron Detector

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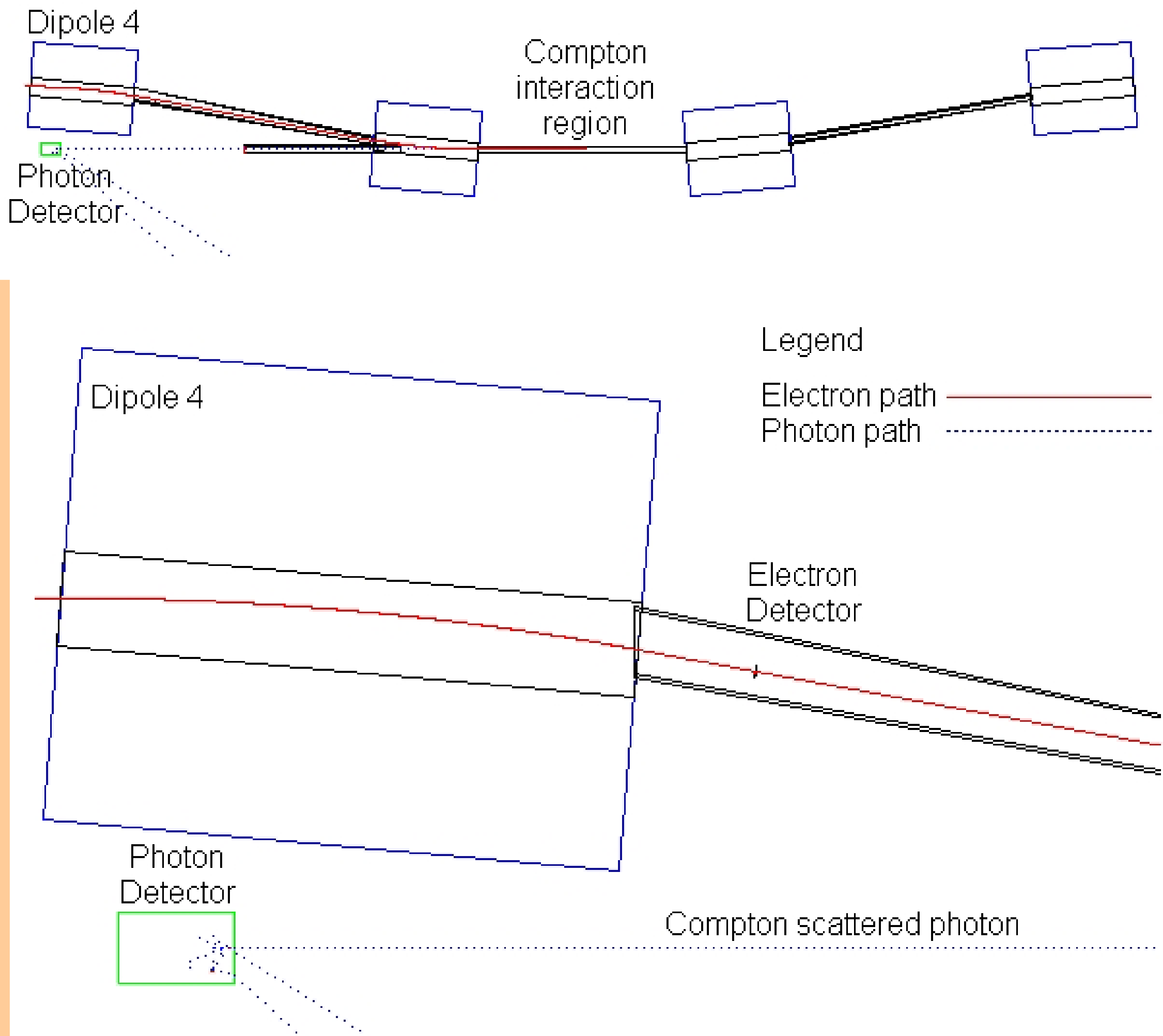
(for Dipangkar Dutta
http://picasaweb.google.com/ddutta07/Riyaz
and the Canadian group)

Outline

- Overview/Funding/Project Management
- Diamond Detectors
- Detector Prototyping Efforts (A. Micherdzinska)
- Electronics Requirements
- Mechanics

Motivation for Electron Detector

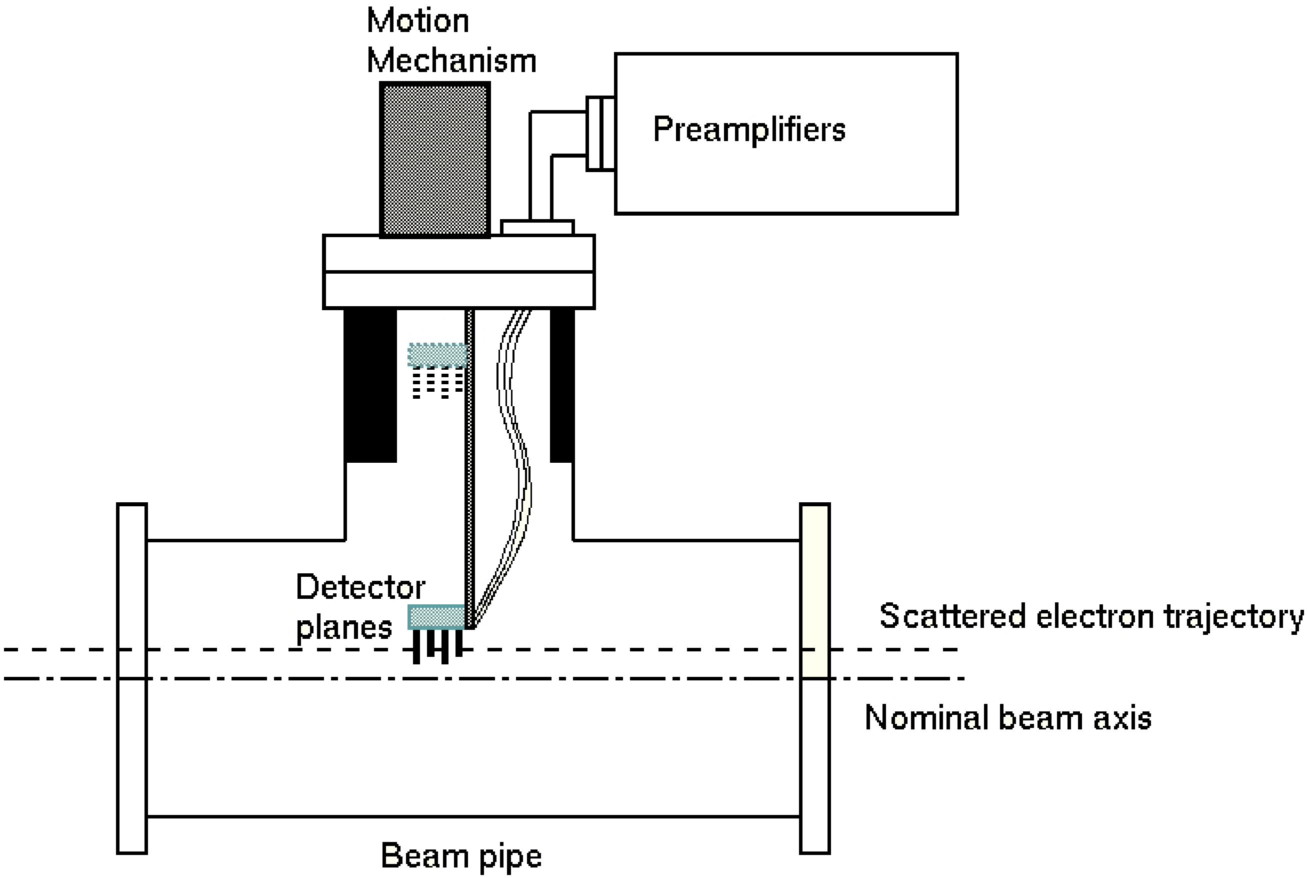


- Position resolution gives momentum of scattered electron.
  - Independent single-arm measurement of polarization
  - Calibration of photon detector (coincidence mode)
- Designing for 1% Polarization Determination for BOTH

Monte Carlo simulation from D. Storey, hons thesis

Technical Overview

- Diamond Detector (4 planes, with 100 strips each)
- Electronics (preamp, discriminator, input module chain)
- Mechanics (pipe, motion mechanism, feedthroughs)



Funding

What we asked for

PI	Requested	Received
Martin	$110kCAD	$85kCAD
Dutta	$75kUSD	prototyping

($17kUSD)

0.5 * detectors
+ 0.5 * electronics
+ 1.0 * mechanics

0.5 * detectors
+ 0.5 * electronics

- Dutta was invited to submit supplemental grant after demonstration of successful prototyping effort.

- Lack of funds in Canadian means we likely need help on mechanics costs.

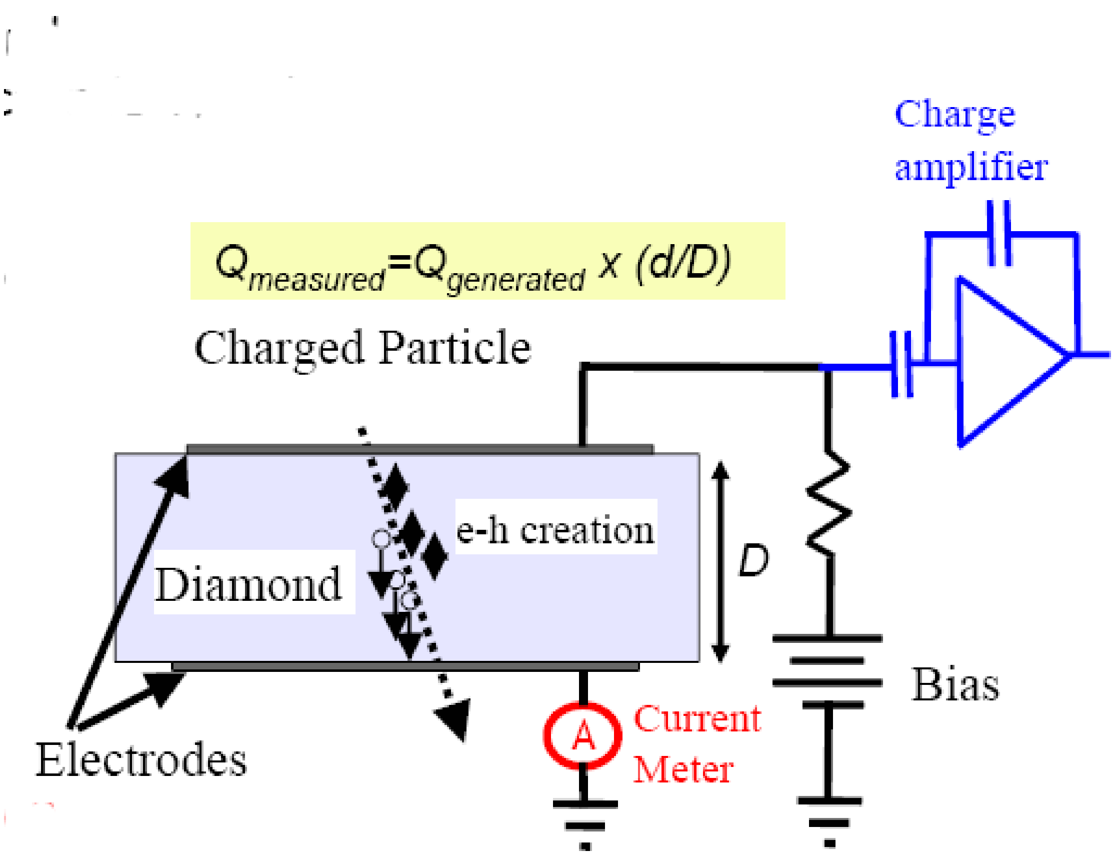
Project Status and Management

- Detector prototyping efforts ongoing
  - close collaboration between MSState and UWpg groups
- Electronics mock-ups at both UWpg and MSState
- Monthly phone meetings with extended Canadian group (others always welcome).

Reports for Today

- Detectors + prototyping
- Electronics
- Mechanics
- Simulation

How a diamond detector works



- Signal limited by impurities and grain boundaries
- Increases with E-field up to ~1-2 V/**μm**
- CCD ("charge collection distance") ~ 250 **μm**

Why pc-CVD diamond?

	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, shot noise

Fast signal collection

Low capacitance, noise

Rad hardness

Smaller signal

sc (single crystal) diamonds are available in sizes up to 8 mm x 8 mm x 0.5 mm
pc (polycrystalline) diamonds are available in huge wafers

-- we will use a 2 cm x 2 cm x 0.5 mm square pc-CVD diamond

Strip trackers have been developed by CERN RD-42 and others using that thickness, available from Element Six (UK spin off of de Beers research)

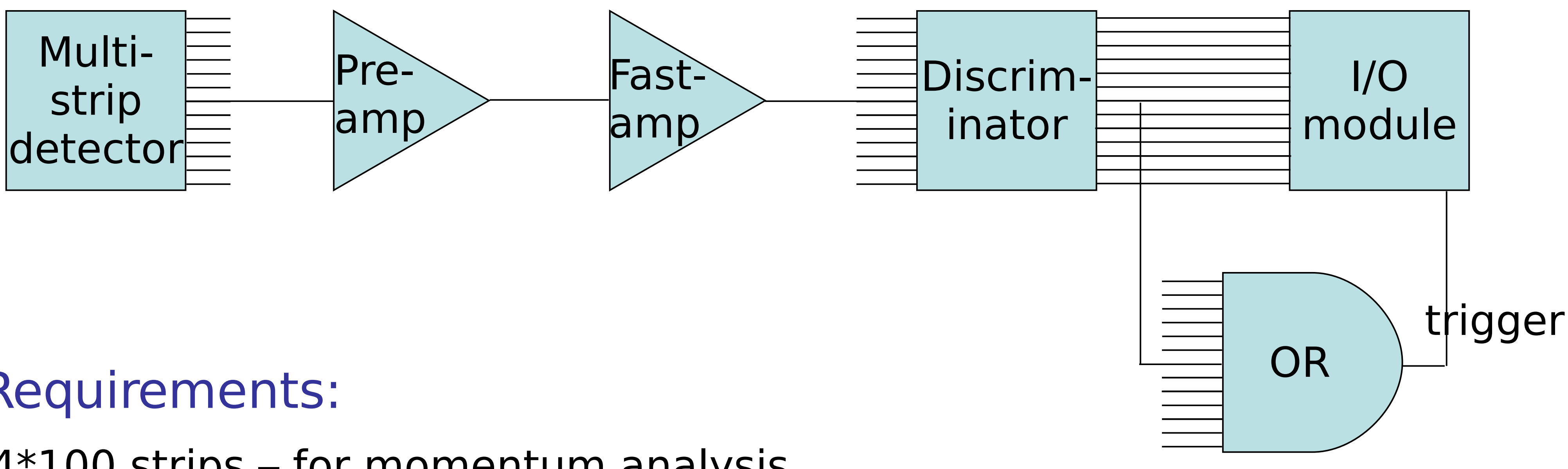
Recent Diamond Progress (More in A. Micherdzinska's talk)

- Coated first test diamond at NSFL (UM EE)
- Visited OSU (Harris Kagan group)
  - learned diamond preparation/metallization in context of a second diamond (D. Dutta's)
  - learned multi-strip detector fabrication
  - learned test procedures
    - CCD measurement
    - I-V curve
  - Successfully fabricated our first working detector
- Coated third diamond (hopefully did it right this time) at NSFL (J. Martin's)

from one of our phone meetings

Compton Electronics

July 3, 2007
Doug Storey, University of Winnipeg



Requirements:

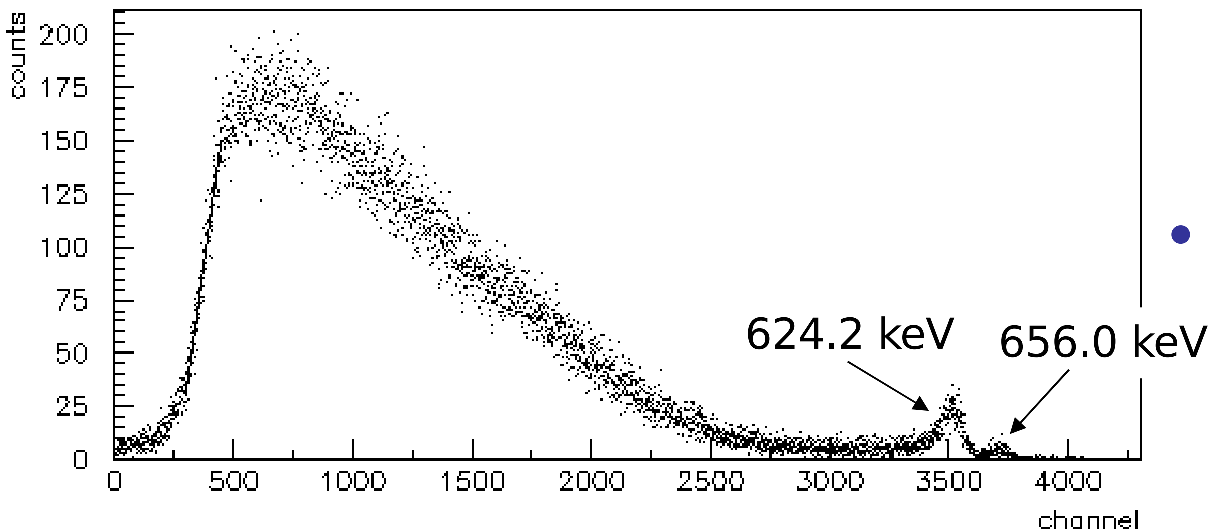
- 4*100 strips – for momentum analysis
- Fast – high rates expected from Compton Scattering + background
- High Amplification – small signal in diamond, ~ ½ silicon

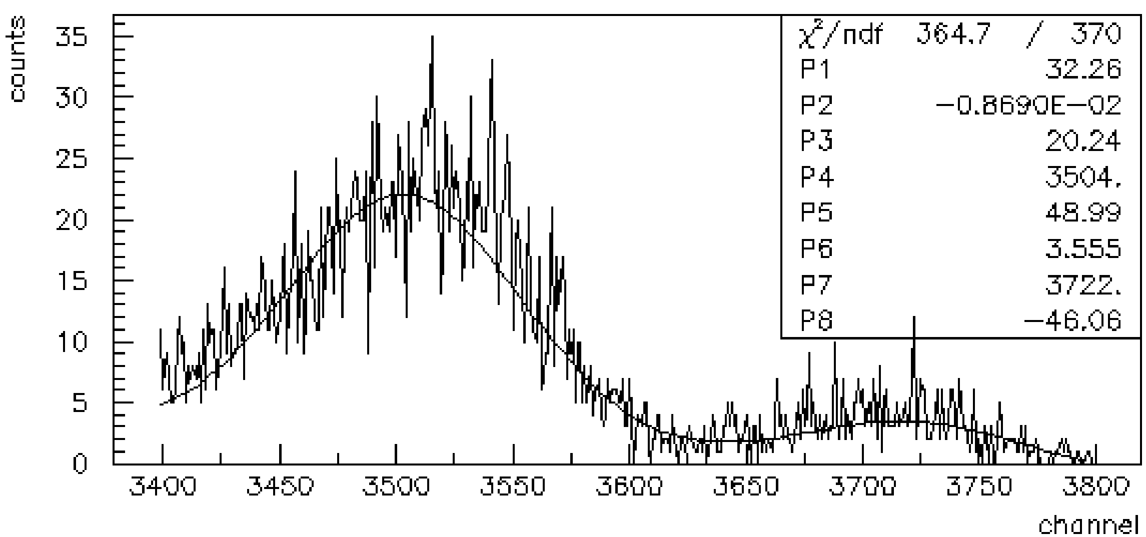
Electronics

- We plan to use existing Hall A VME system (Bertin, Clermont-Ferrand).
- Hall A upgrade did not replace these electronics, they simply built more of them.
- Discussions ongoing with Bertin. We are trying to get prototype modules.
  - could use assistance on this (TRIUMF?)
- Might need to build our own preamps, due to silicon/diamond differences.
- Enough alternate electronics exist at UWpg/MSState for tests
  - MESYTEC system – D. Storey, UWpg

UWpg MESYTEC tests (D. Storey)

Cesium-137 Spectrum

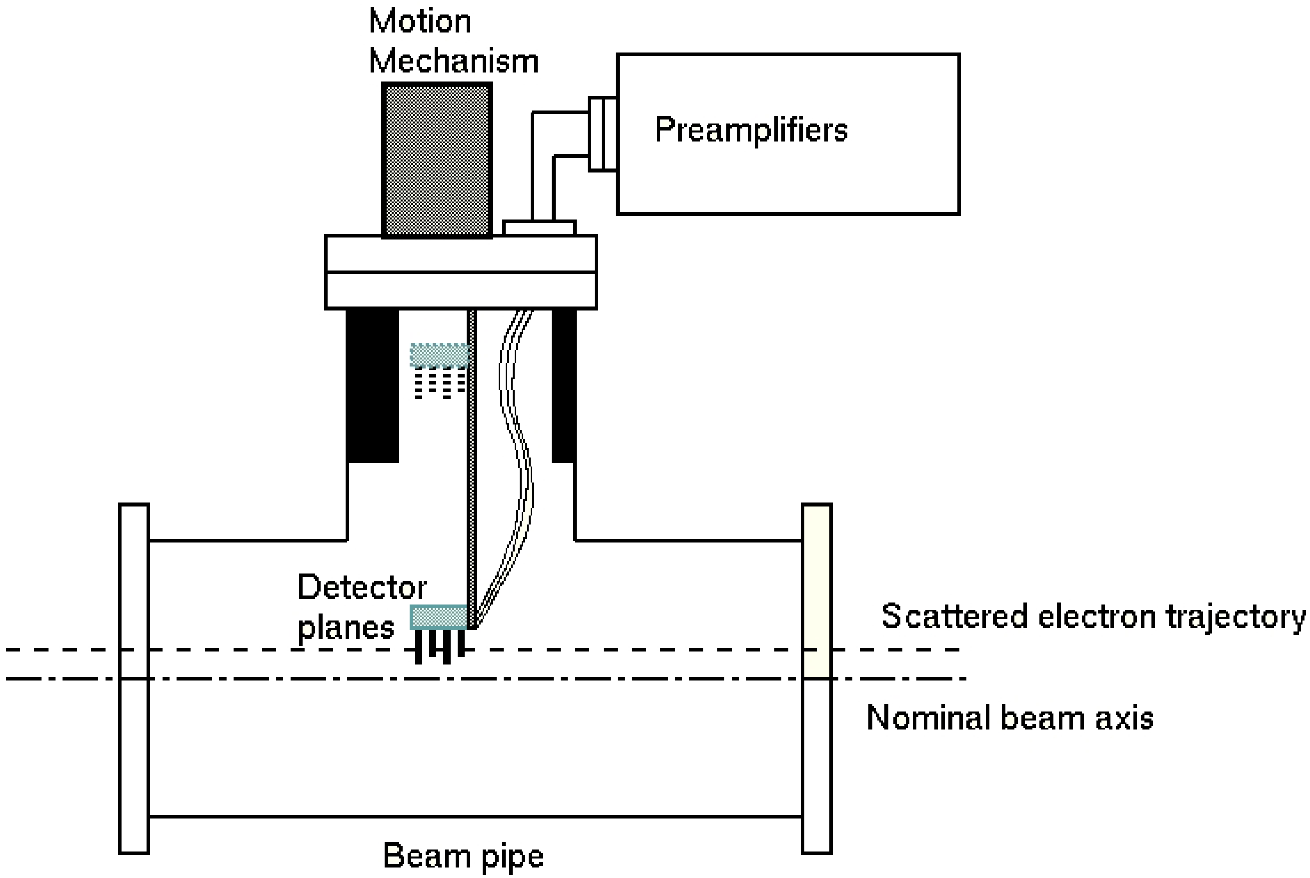




Tests so far have been done with silicon detector and various sources (e.g. Cs-137)

- **Preamp Gain**
  - ~7.5 times greater gain then **ORTEC** 109A (7.5*150mV/MeV Si equiv.)
- **ADC Energy Resolution**
  - very similar to **ORTEC**,
    - σ ~ 7-8 keV
  - limited by Si, or method?
- **Characterizing Discriminator Threshold**
  - Should be able to reach low enough threshold for diamond, with these electronics
- **Future steps**
  - Constructing test box for diamond samples.
  - Ready for multi-strip tests
  - Purchase VME input module

Mechanics



- Manpower available.
- Equipment costs TBD with JLab

Mechanics Cost Est. (from Canadian proposal)

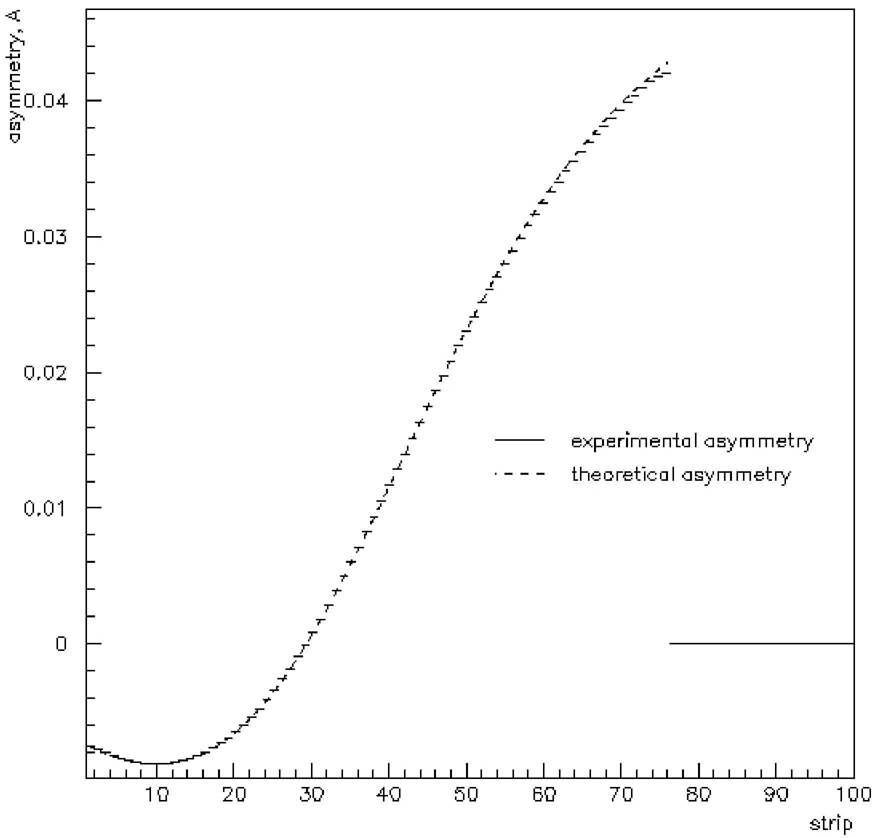
Item	Cost (CAD)
Detector Mount	$1k
Motion Mechanism and Feedthrough	$10k
Section of Beam Pipe	$7k
Detector Garage Pipe	$8k
Custom Flanges and Adapters	$8k
Total	$34k

- based on quotes from MDC website
- need to get a more realistic design (TRIUMF?)

Monte Carlo Electron Detector Simulation

- D. Storey, hons thesis, and continuing work through this summer.

Asymmetry

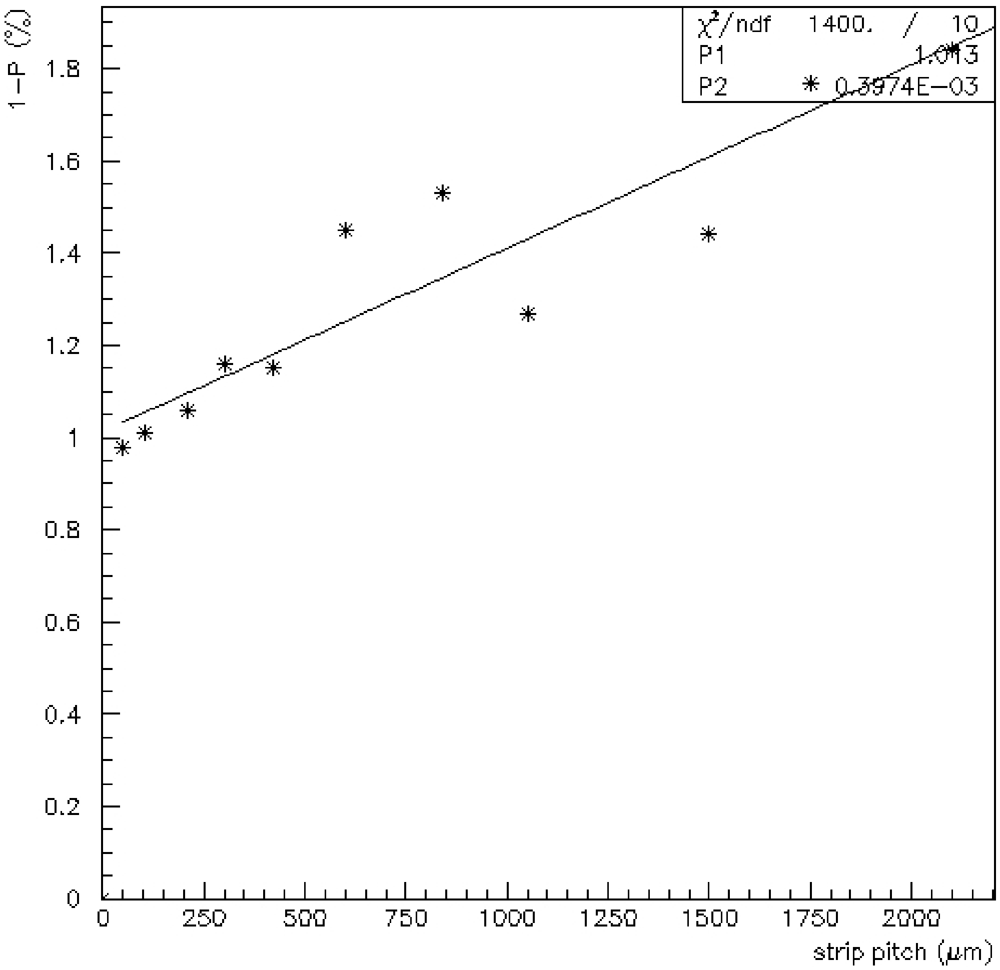


- Measuring polarization by fitting the asymmetry function to the experimental asymmetry

$$A_{exp} = P_1 \frac{(1-((x-P_2)P_3)(1+a))\left(1-\frac{1}{(1-((x-P_2)P_3)(1-a))^2}\right)}{\left[\frac{((x-P_2)P_3)^2(1-a)^2}{1-((x-P_2)P_3)(1-a)}+1+\left(\frac{1-((x-P_2)P_3)(1+a)}{1-((x-P_2)P_3)(1-a)}\right)^2\right]}$$

- P_1 is polarization
- P_2 and P_3 are energy calibration parameters of strip vs. momentum

Monte Carlo Electron Detector Simulation



- 1% limit in polarization extraction using curve fitting method
  - should be able to measure polarization *exactly* with a fine enough strip pitch
- Expected to go as*:

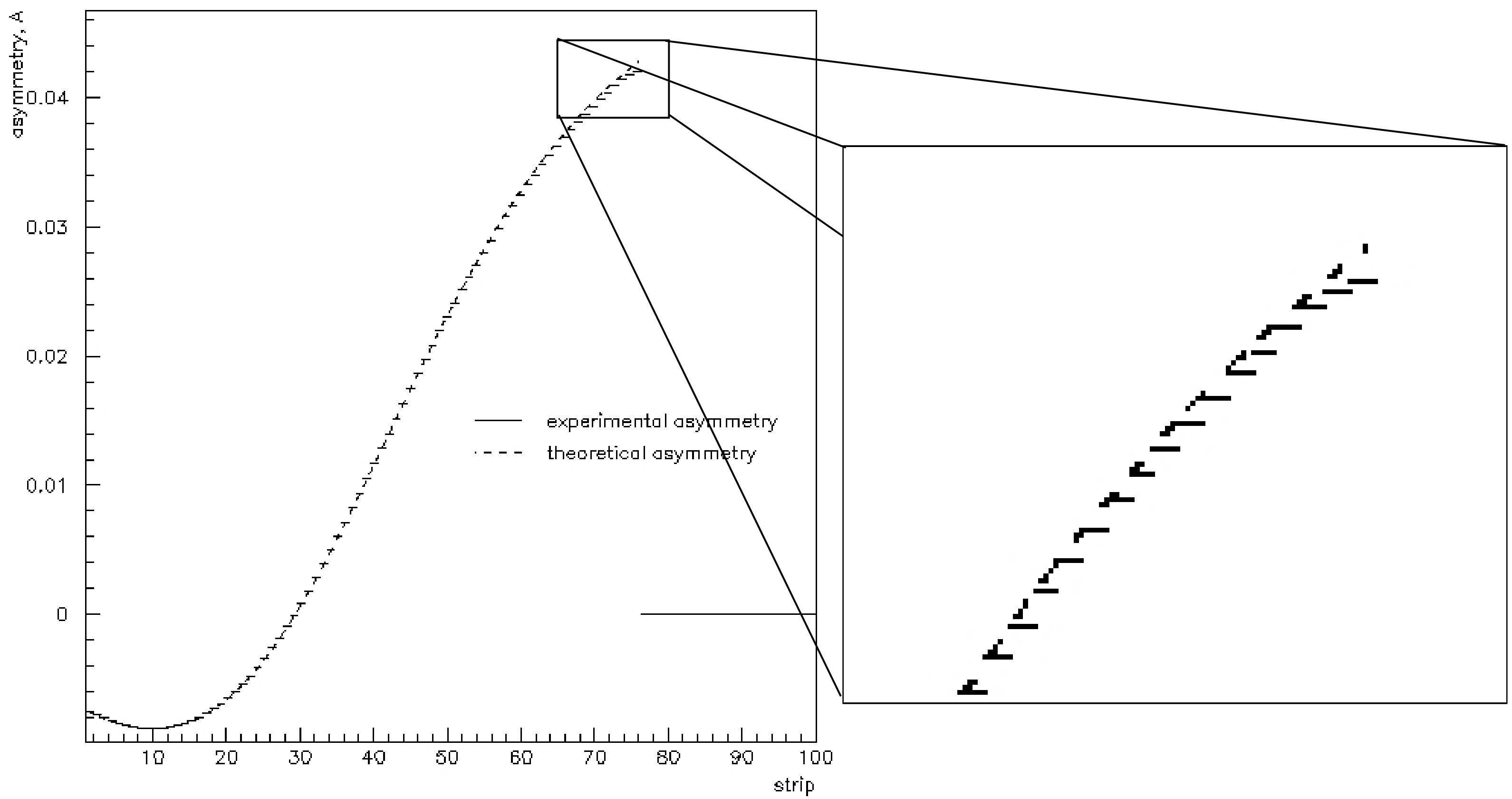
$$\frac{\Delta P_e}{P_e} = 2 \times \frac{\Delta Y}{Y_{\max}}$$

- Not entirely due to beam width as predicted in thesis

*D. Lhuillier, presentation at HAPPEx collaboration meeting, Dec. 3, 2005.

*S. Nanda and D. Lhuillier, "Draft Conceptual Design Report for Hall A Compton Polarimeter Upgrade", Feb. 12, 2004. Available from: http://hallaweb.jlab.org/parity/prex/

Monte Carlo Electron Detector Simulation



- 1% limit due to non-linearity of strip w.r.t. backscatter photon energy, ρ
  - Suggested by the deviation in asymmetry (cf. theory) near the Compton edge
  - Confirmed in studies of nonlinearities in strip vs. momentum.
  - Need to cope with this for momentum determination at 1% level
  - Even understanding this, we have difficulty reproducing L'Huillier's result (dP/P~2dy/y) in our Monte Carlo
  - unless this is from “zero-crossing to Compton edge” integration.

Summary

- Funding in place
- Detector prototyping work has begun
  - A. Micherdzinska's talk – next
    - MSState will design proto carrier board
    - UWpg will replicate OSU metallization process
- Electronics and Mechanics
  - need to get going on this.
- Monte Carlo work is fairly advanced, but still some mysteries which are being uncovered – would be nice to have more detailed info from Hall A.