Compton Polarimeter Electron Detector

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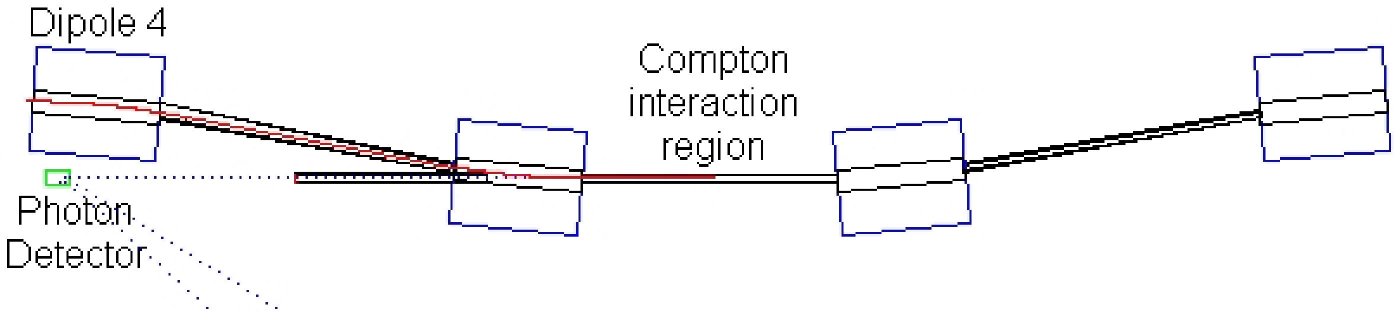
(for Dipangkar Dutta
http://picasaweb.google.com/ddutta07/Riyaz
at MSState and for the Canadian group)

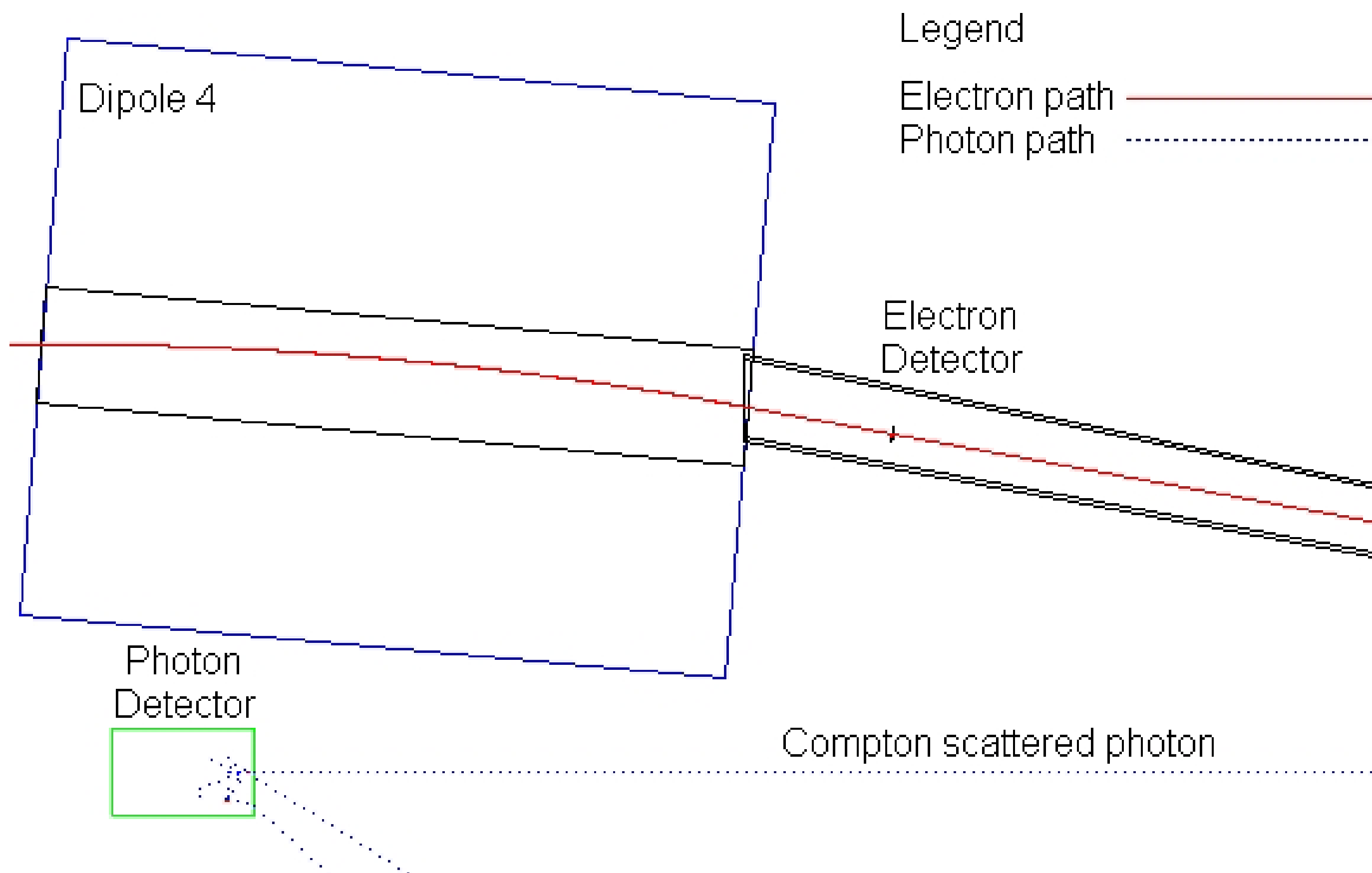
Outline

- Overview/Funding/Project Management
- Diamond Detectors
- Detector Prototyping Efforts
- Electronics Requirements
- Mechanics

Motivation for Electron Detector



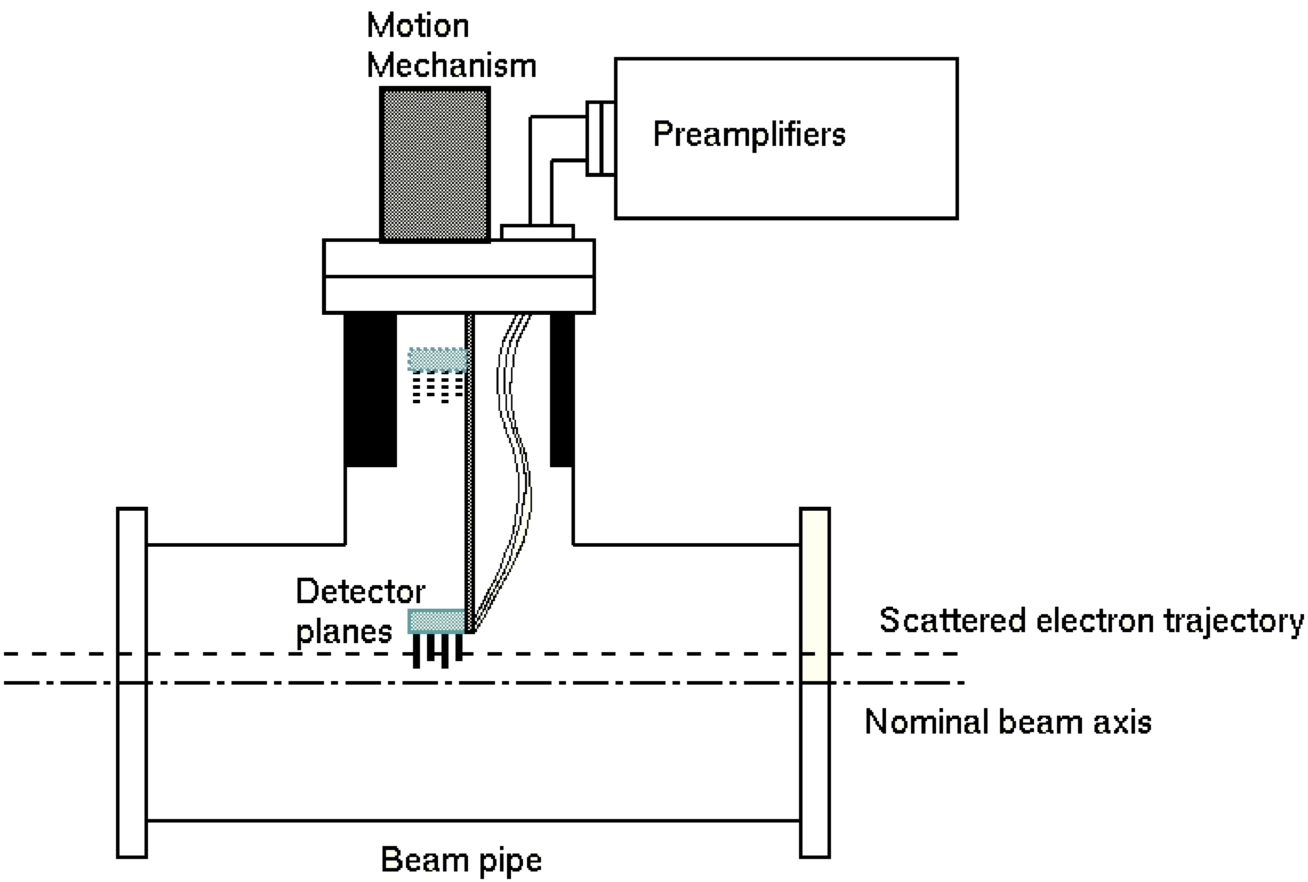
- Position resolution gives momentum of scattered electron.
  - Independent single-arm measurement of polarization
  - Calibration of photon detector (coincidence mode)
- Designing for 1% Polarization Determination for BOTH



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.

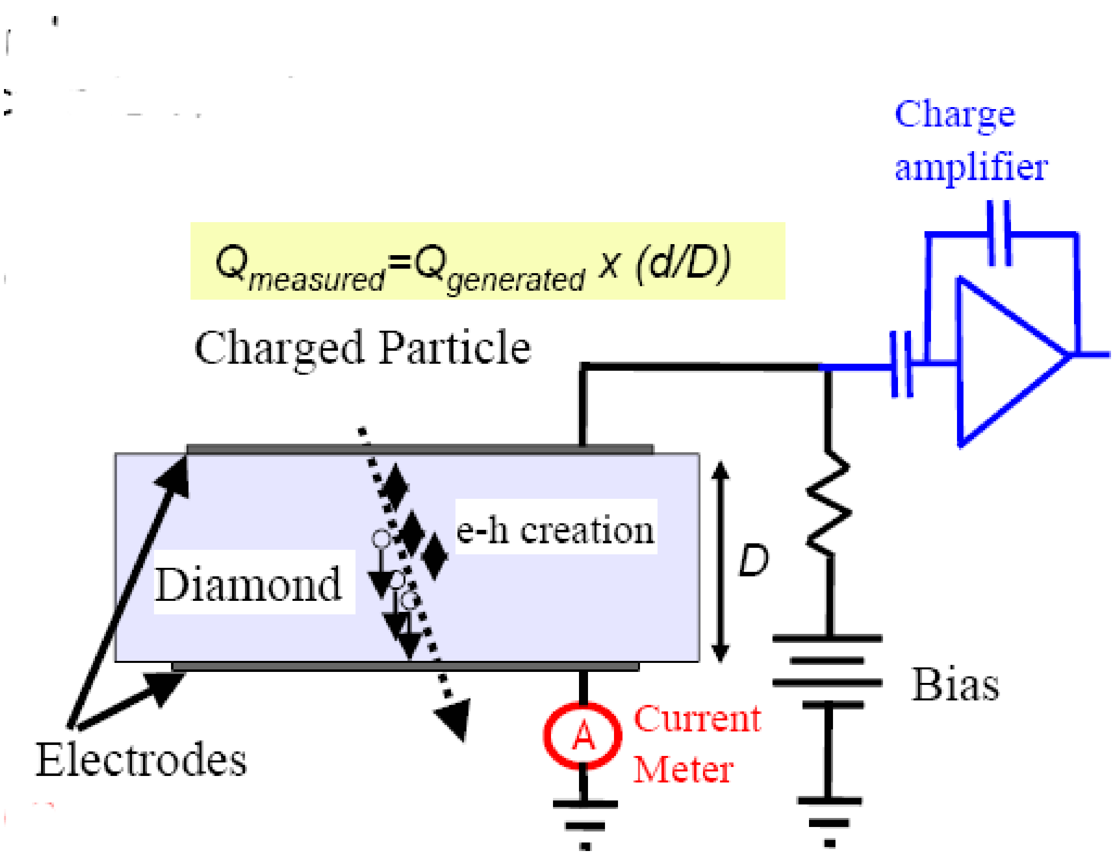
Project Status and Management

- Detector prototyping efforts have had some success
  - close collaboration between MSState and UWpg groups
  - experience of OSU and UToronto groups (CERN RD42)
- 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	Low leakage current, shot noise
Electron/Hole mobility (cm^2/Vs)	1450/500	2200/1600	Fast signal collection
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	Low capacitance, noise
Displacement energy (eV)	13-20	43	Rad hardness
e-h creation energy (eV)	3.6	13	
Av. e-h pairs per MIP per micron	89	36	Smaller signal
Charge collection distance (micron)	full	~250	

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

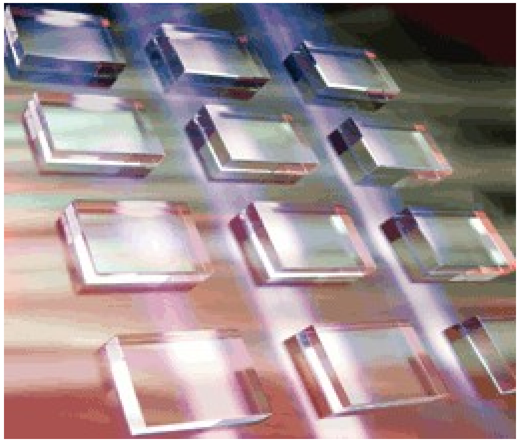
- Coated first test diamond at NSFL (UM EE)
- Visited OSU (Harris Kagan group)
  - learned diamond preparation/metallization in context of a second diamond (D. Dutta's)
  - learned multi-strip detector fabrication
  - learned test procedures
    - CCD measurement
    - I-V curve
  - Successfully fabricated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

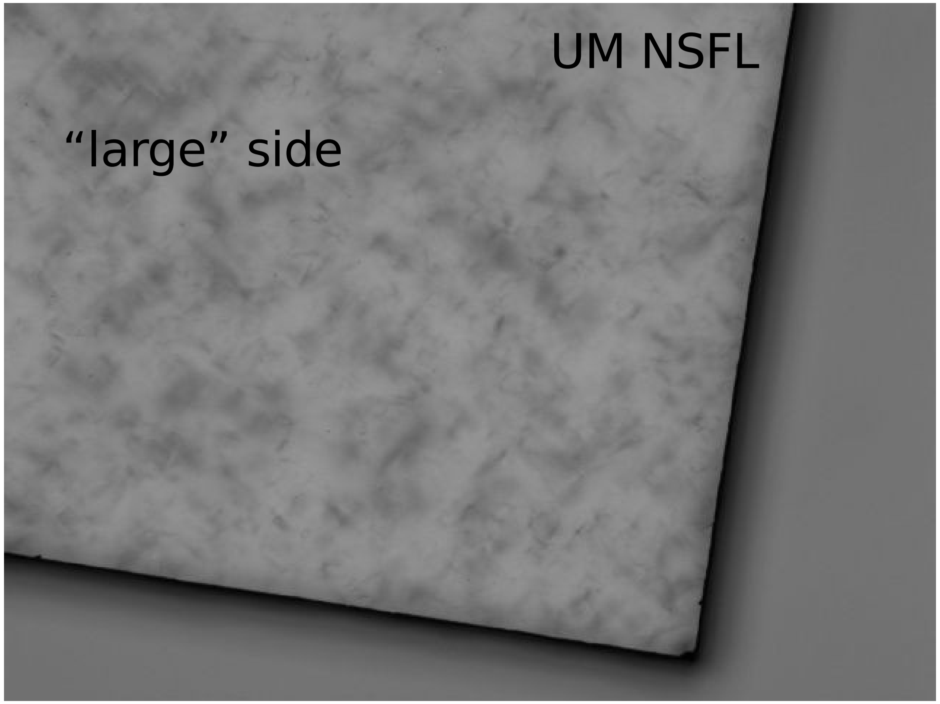
How to make a diamond detector

1. Get a “CERN grade” diamond from elementsix

ADVANCING DIAMOND

- Dutta and Martin each ordered:
  - 1 cm x 1 cm x 500 um
  - PC-CVD



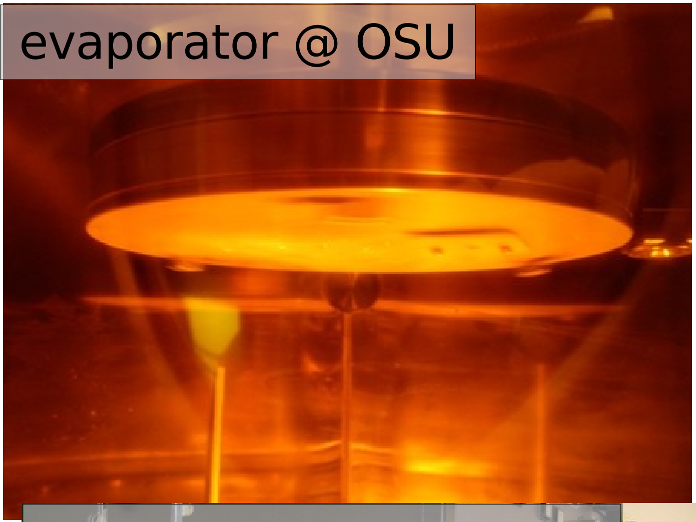


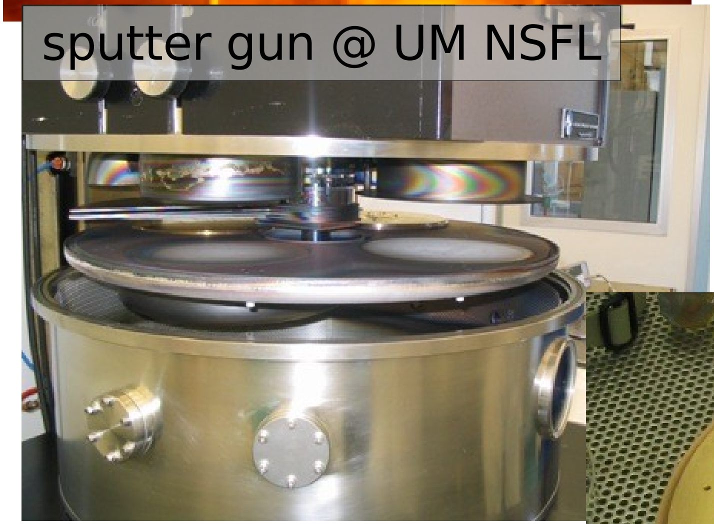
2. Boil in various acids/bases.

- cleans off the surface
- attempt to replace H-terminated surface with O-terminated (oxidizing agents like H_2O_2)
- follow with low-power plasma etch in O_2 environment

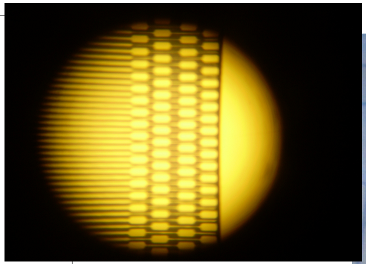
3. Lay down some metal

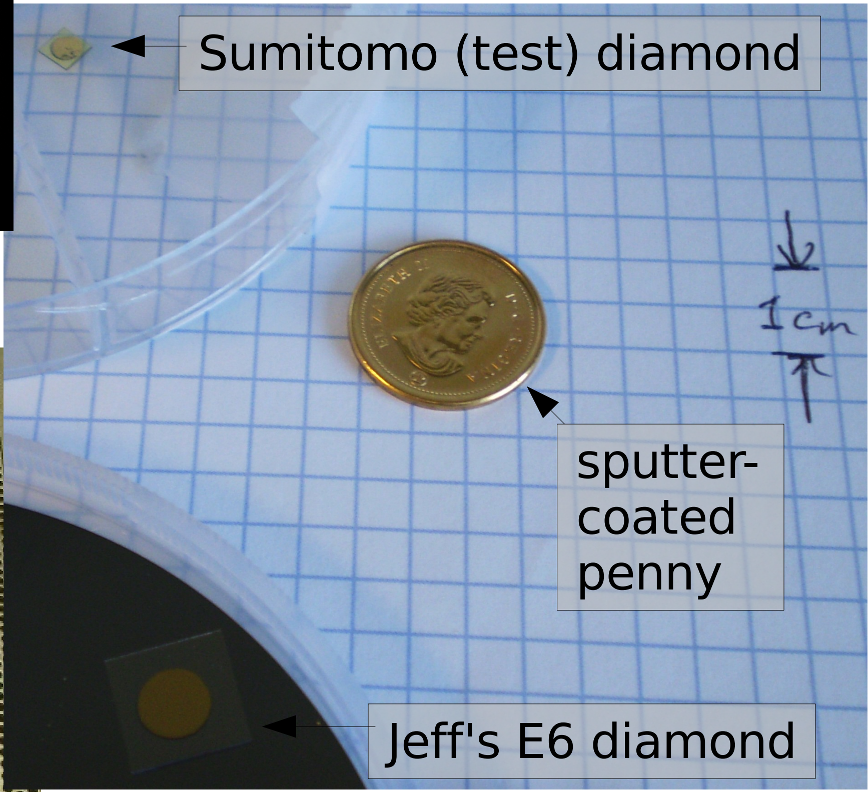
- sputter or evaporate
- test detectors usually done with Cr (50 nm) / Au (200 nm)
- shadow mask used for "dots"
- photolithography ("lift-off") used for strips.
- OSU procedure: dots, then strips, for <u>every</u> diamond.



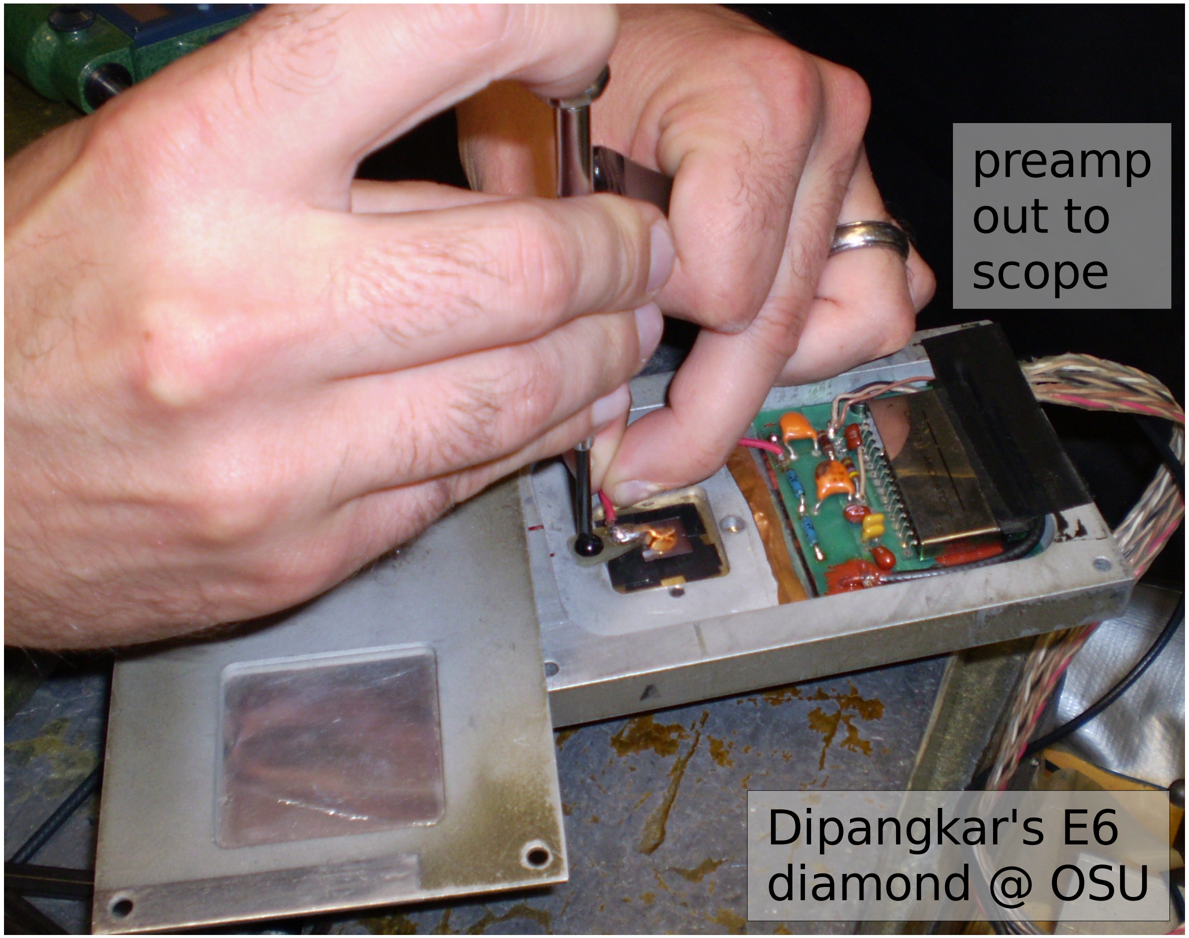


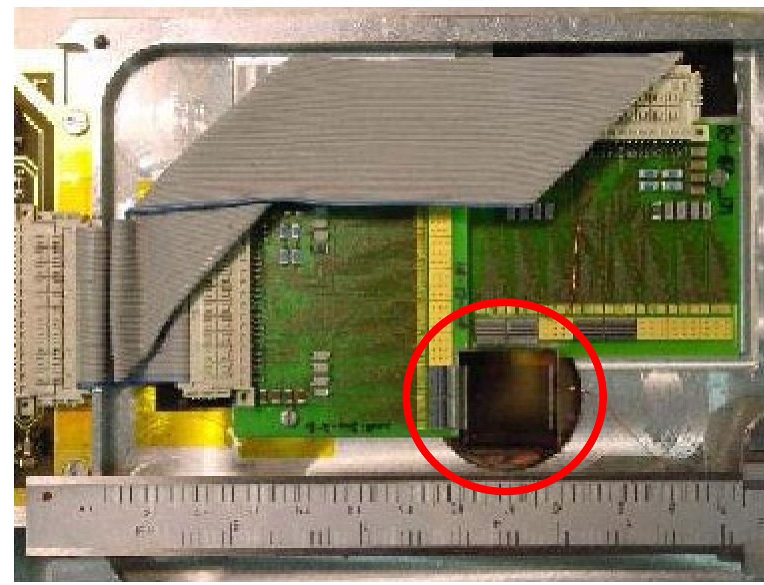
strips on glass @ OSU 50 um pitch





4. Test / mount in package





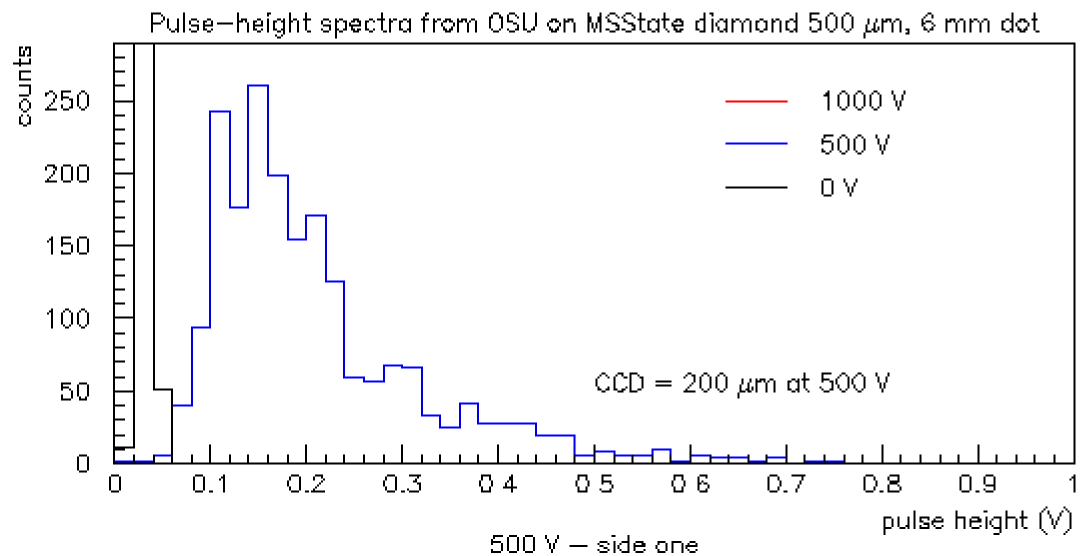
RD42-owned diamond strip
tracker with seven planes,
50 um strip pitch.

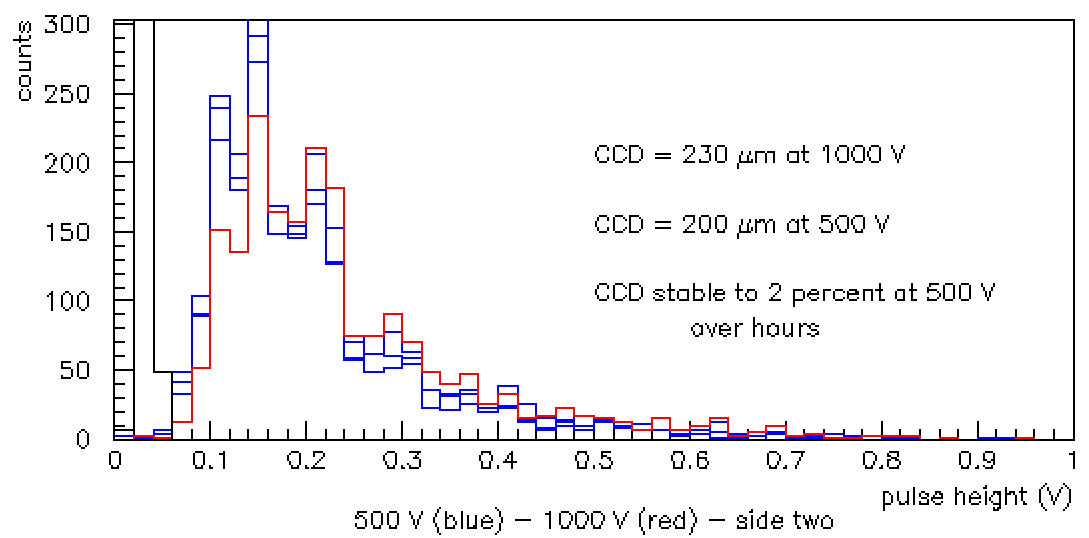
Test procedures

- With dots
  - tape test
    - see if the metal comes off with tape
  - I-V curve measurements
    - apply voltage and measure leakage current
      - typ. 1 pA for 1000 V for 6 mm Φ dots.
      - long settling time
  - CCD measurement
    - use a collimated 90Sr source to find the "charge collection distance" (distance you can pull apart an e-h pair before they are lost to recombination)
- Then etch off the dots and lay down strips

CCD Results for Dipangkar's E6 Diamond @ OSU

- We got good results for our first dot! (with lots of help from OSU)
- CCD "typical"
- Next steps:
  - replicate OSU dot process (UWpg)
  - design multistrip test (MSState)



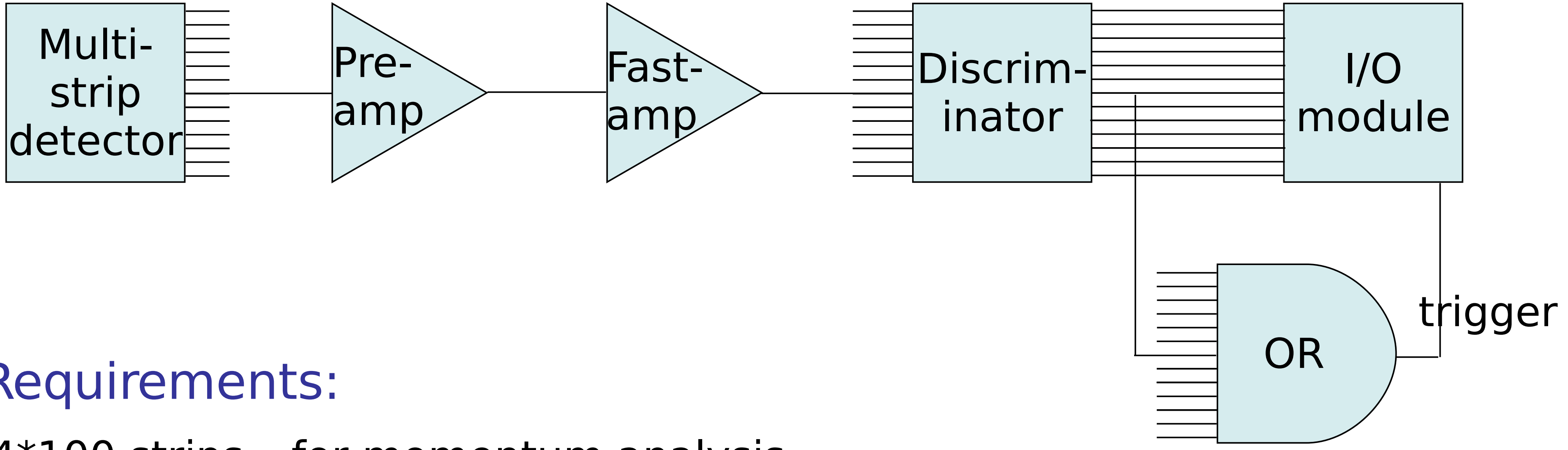


from one of our phone meetings

Compton Electronics

July 3, 2007

Doug Storey, University of Winnipeg



Requirements:

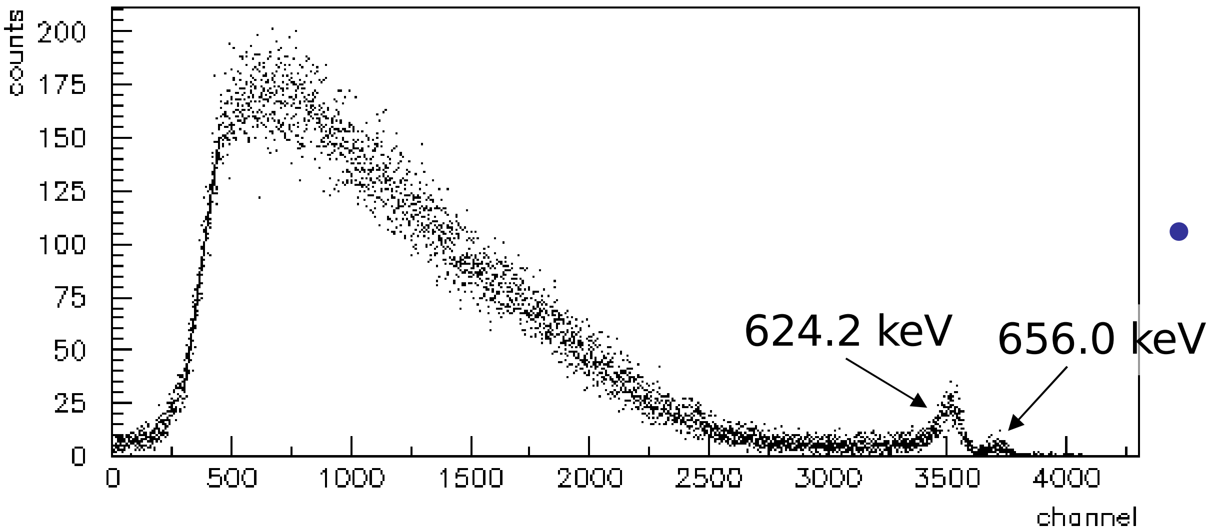
- 4*100 strips – for momentum analysis
- Fast – high rates expected from Compton Scattering + background
- High Amplification – small signal in diamond, ~ ½ silicon

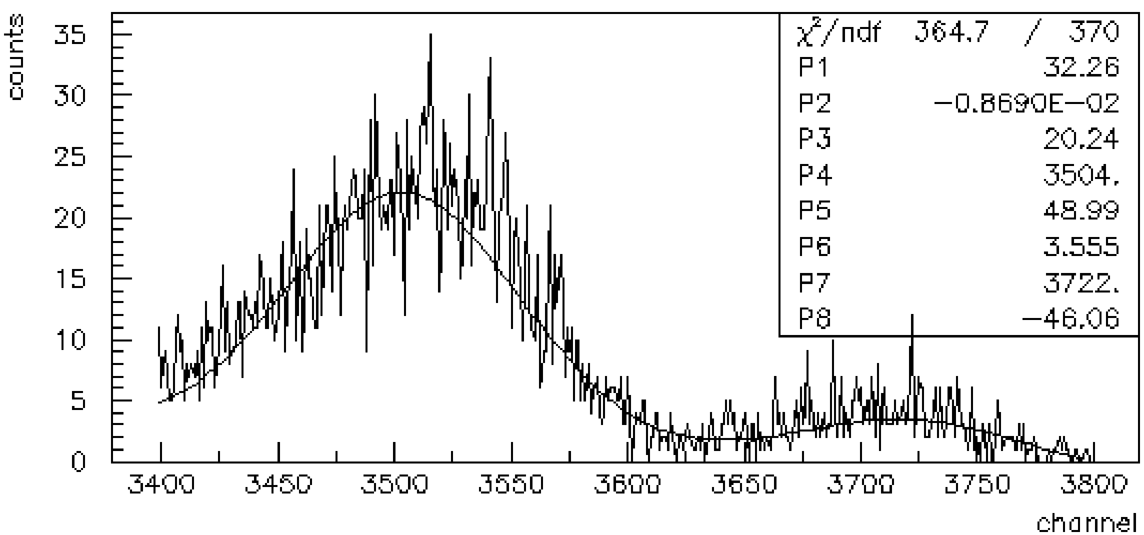
Electronics

- 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

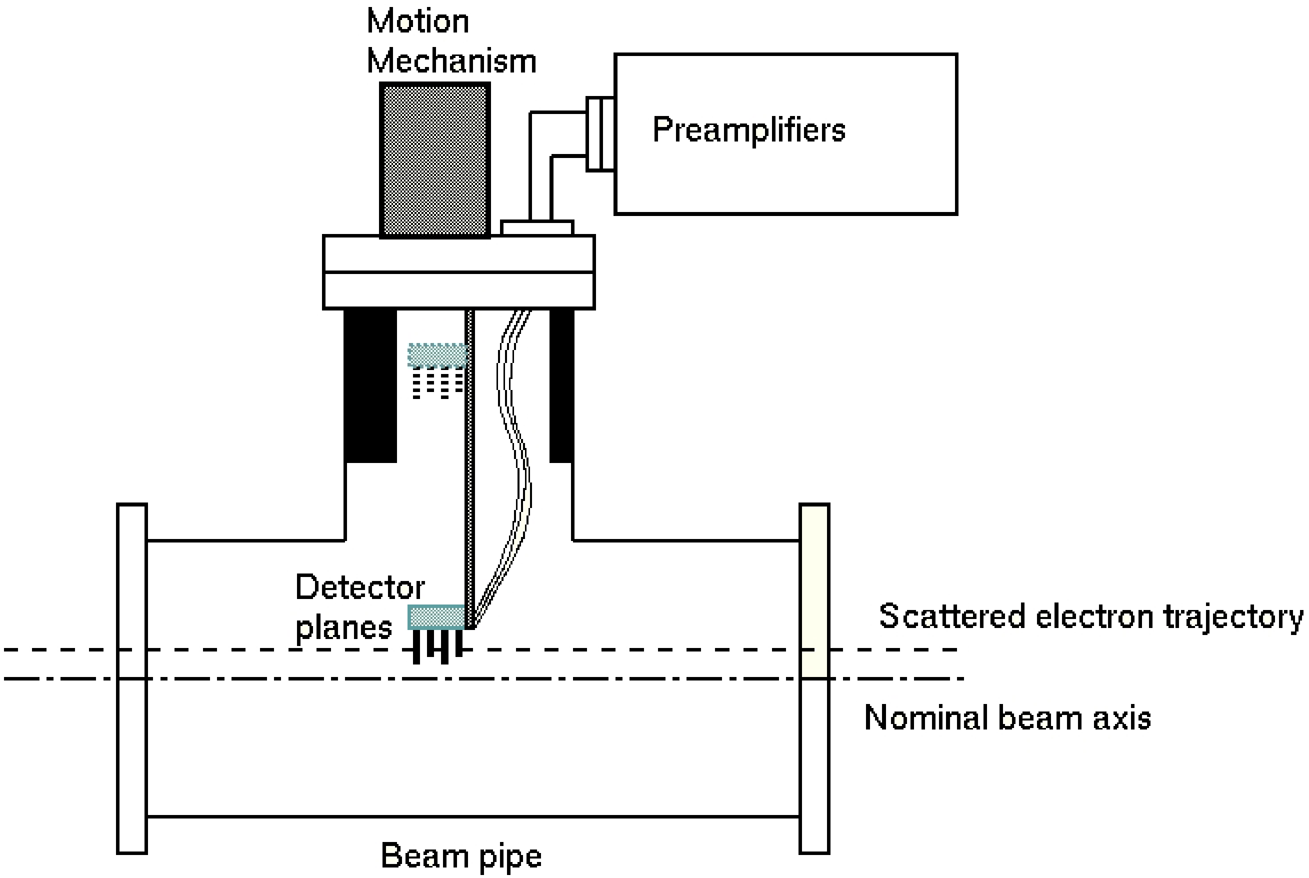




Tests so far have been done with silicon detector and various sources (e.g. Cs-137)

- **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?)

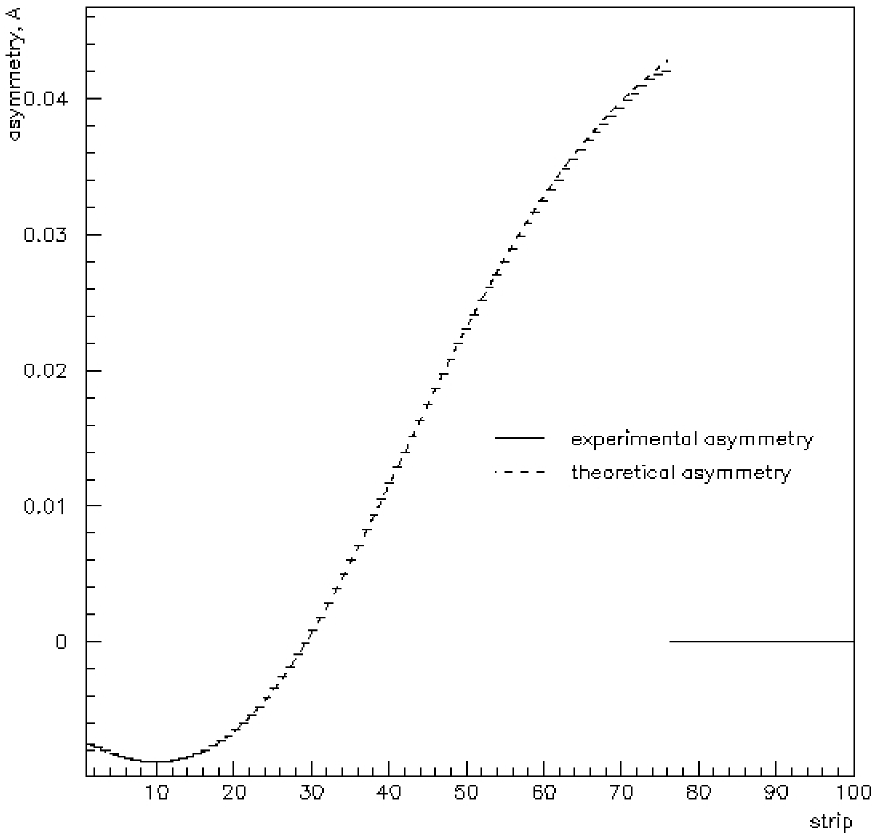
Ideas on Budget Shortfall (discussion from collab. meeting)

- Ask JLab to pay for “mechanics” (Martin et al)
- Ask JLab to pay for “spares” (Carlini)
- Since we've got a working prototype, go back to NSERC and ask for the rest of our money! (van Oers, Page) Dipangkar was approved, but has to go back to DOE for more money, too.

Monte Carlo Electron Detector Simulation

- D. Storey, honours thesis, and continuing work through this Friday.

Asymmetry

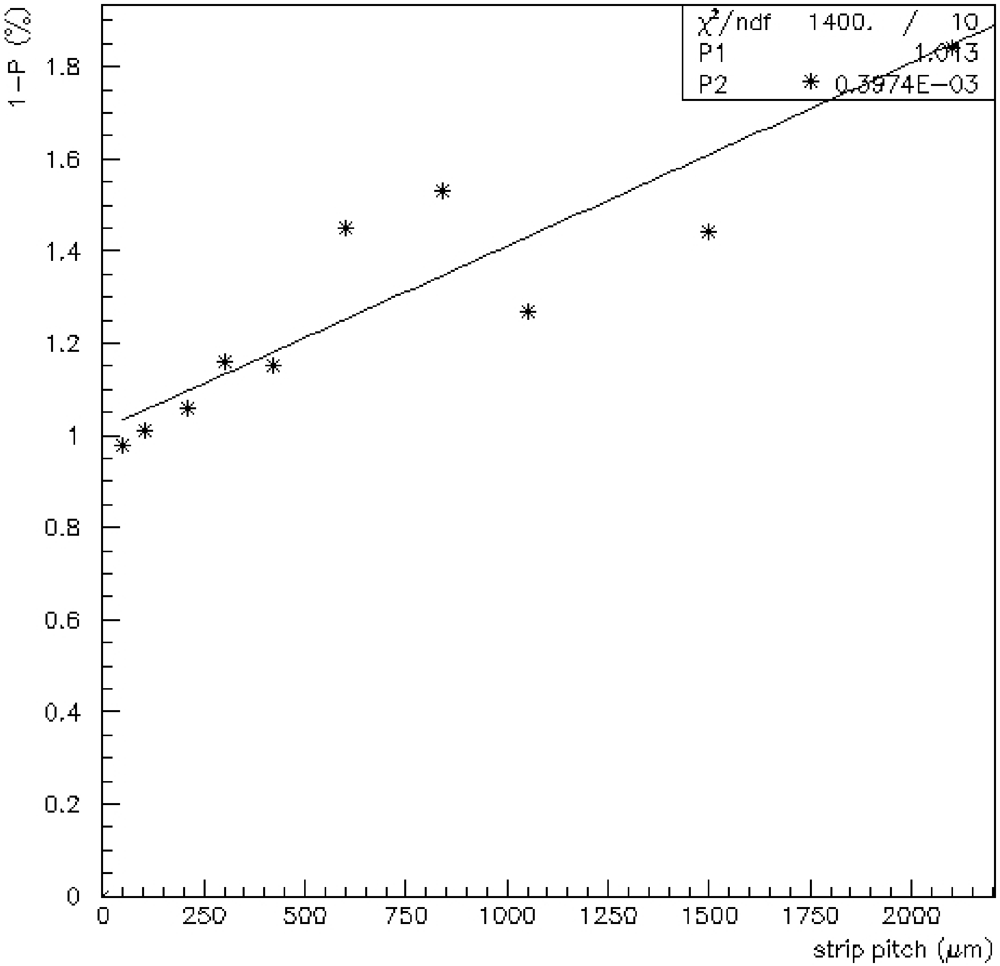


- Measuring polarization by fitting the asymmetry function to the experimental asymmetry

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

- 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*:

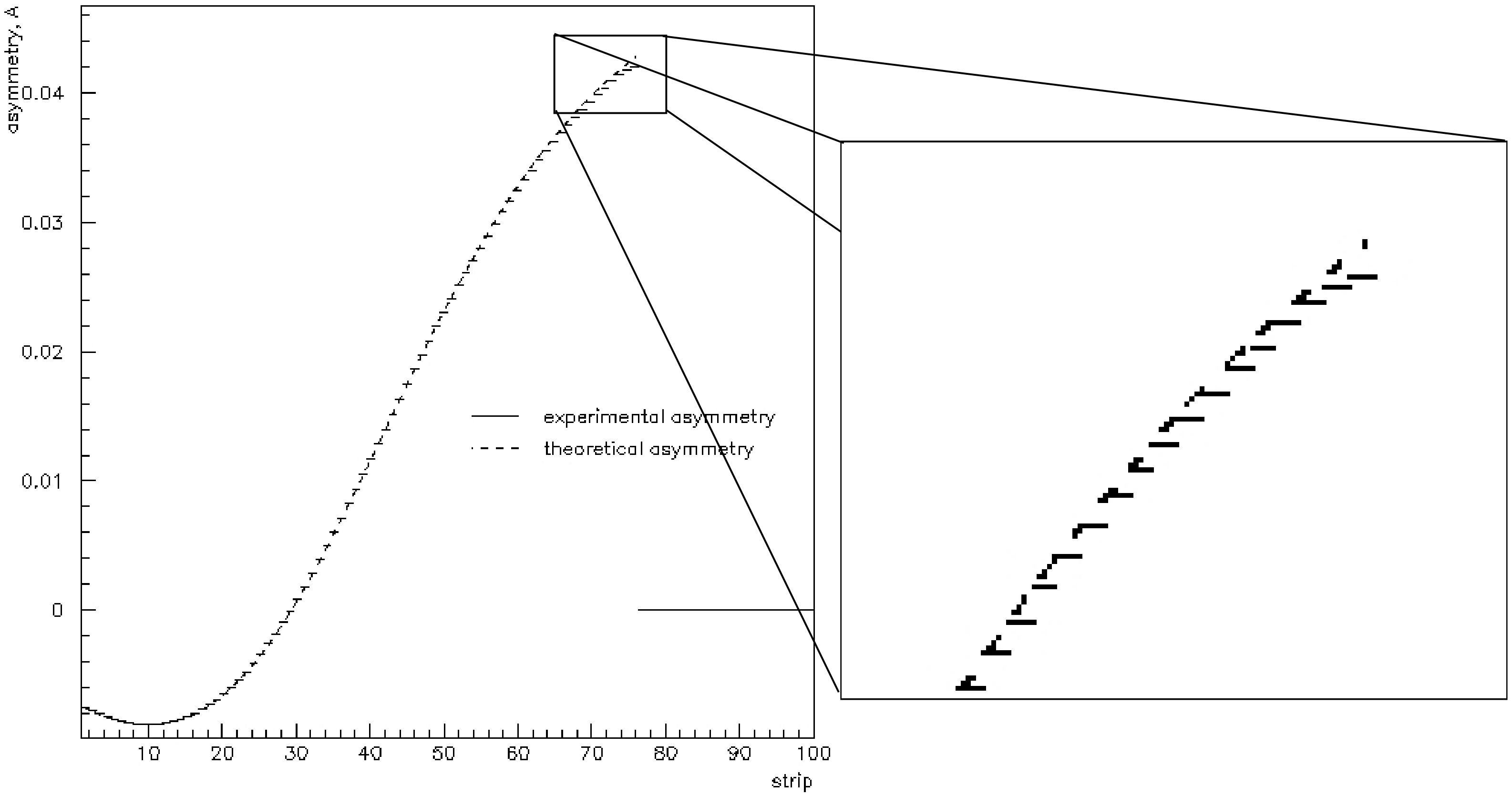
$$\frac{\Delta P_e}{P_e} = 2 \times \frac{\Delta Y}{Y_{\text{max}}}$$

- 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/

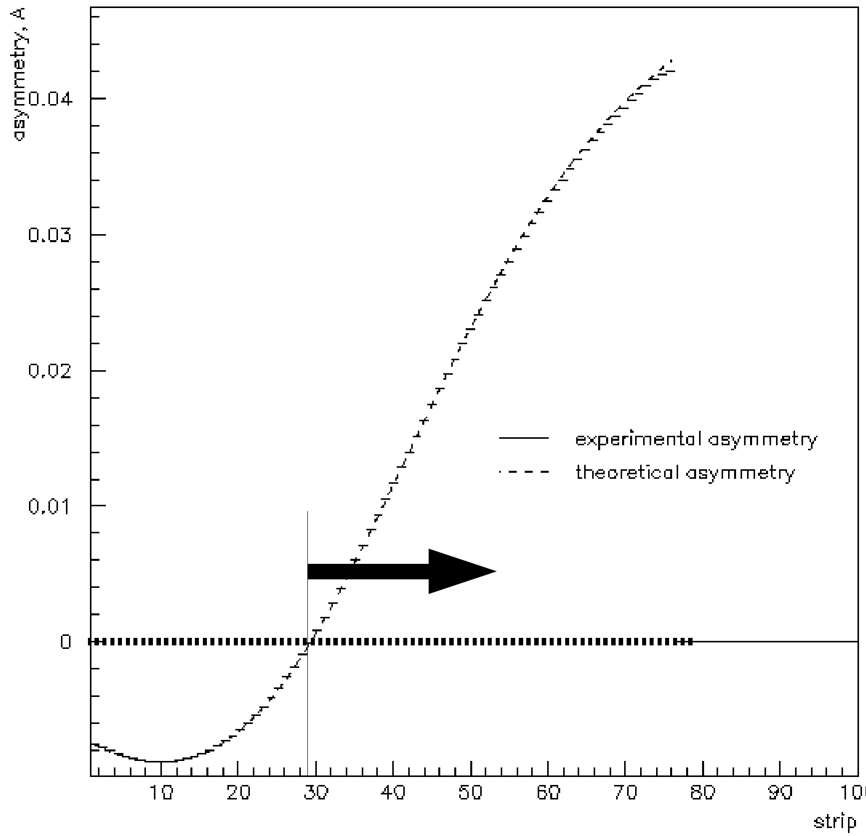
Monte Carlo Electron Detector Simulation



- 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.

Since collab meeting -- Doug did more MC work

- Doug can reproduce dP/P ~ dy/y if using integration method and ("high"-"low")/2 as estimate of polarization error (vary around the zero-crossing of the asymmetry).
- Factors of two still not sure about.



"low" = integrate from strip #28
"high" = integrate from strip #30

Summary

- Funding in place
- Detector prototyping work has begun
  - Our first dot prototype worked!!!
  - 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.