PREx Compton Polarimeter Project Summary

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PREx Goal: Asymmetry measured to 3%

Beam Polarimetry precision goal 1% to 2%

- Upgrade to *green* laser
  (1064 nm --> 532 nm)

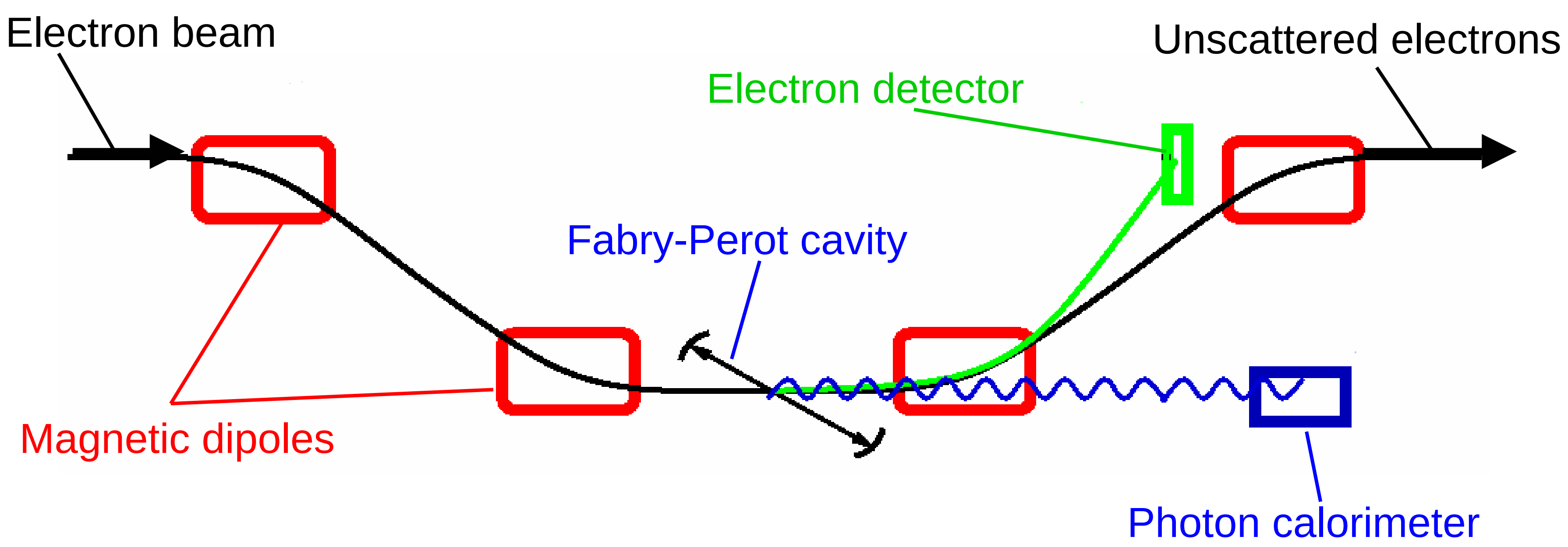
- Compton photon *energy integrating* technique
  $WPbO_4$ array replaced with single GSO crystal
  Use flash-adc to sum photon energy

- Coincident-electron μstrip used for calibration

See: *Conceptual Design Report for Hall A Compton Polarimeter Upgrade*, Nanda and Lhuillier

The Compton Polarimeter

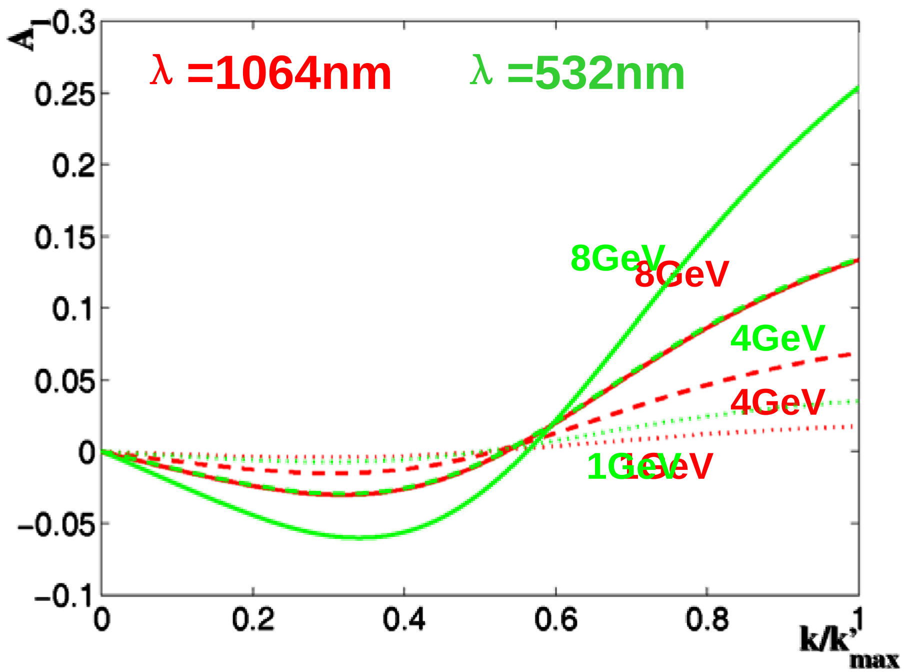
- Laser light is injected into Fabry-Perot cavity, which amplifies the power
- Electron beam passes through chicane and into cavity
- Detect scattered electrons and photons
- Unscattered electrons continue downstream



Compton Cavity Upgrade

- The error of a Compton polarimeter depends inversely on the longitudinal asymmetry A_l:

$$\frac{\Delta P_e^{syst}}{P_e} \propto \frac{1}{A_l}$$



- Halving the photon wavelength (from 1064 nm to 532 nm) effectively doubles A_l

Energy Weighted Asymmetry:

$$E^{\pm} = LT\int_0^{E_{\max}} \varepsilon(E)E\frac{d\sigma}{dE}(E)\left(1 \pm P_e P_\gamma A_l(E)\right)dE$$

$$A_{Exp} = \frac{E^+ - E^-}{E^+ + E^-}$$

Longitudinal Compton Asymmetry

Actual Asymmetry Weighted by Detector Signal

$$S^{\pm} = LT\int_0^{E_{\max}} s(E)\frac{d\sigma}{dE}(E)\left(1 \pm P_e P_\gamma A_l(E)\right)dE$$

Average detector signal for photon energy *E*

$$A_{Exp} = \frac{S^+ - S^-}{S^+ + S^-} = P_e P_\gamma \frac{{}_\gamma\int_0^{E_{\max}} A_l(E)S(E)\frac{d\sigma}{dE}(E)dE}{\int_0^{E_{\max}} S(E)\frac{d\sigma}{dE}(E)dE} = P_e P_\gamma A_{lS}$$

Need to **minimize** uncertainty in A_{ls}

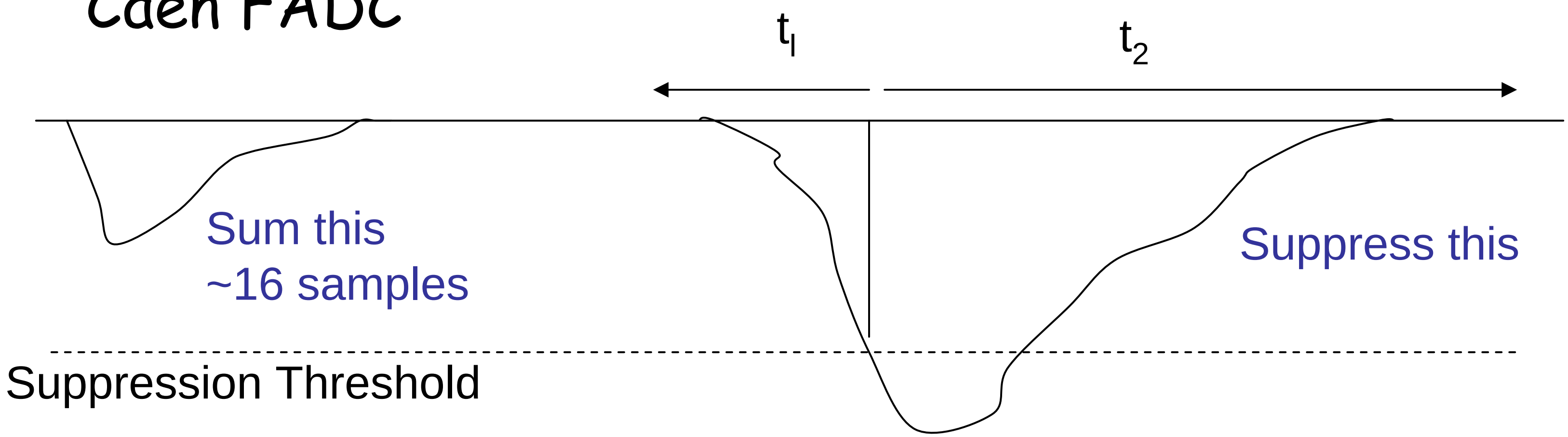
- Use single GSO crystal (Gd_2SiO_5)
  - simplify detector response modeling
  - 30x more light than PbWO (20% of NaI)
  - 80 ns decay time
  - 6.7 g/cm^3

6 cm diam x 15 cm length coming from Hitachi Chemical

(GEANT4 simulations: see Diana Parno talk)

Need to **minimize** uncertainty in A_{ls}

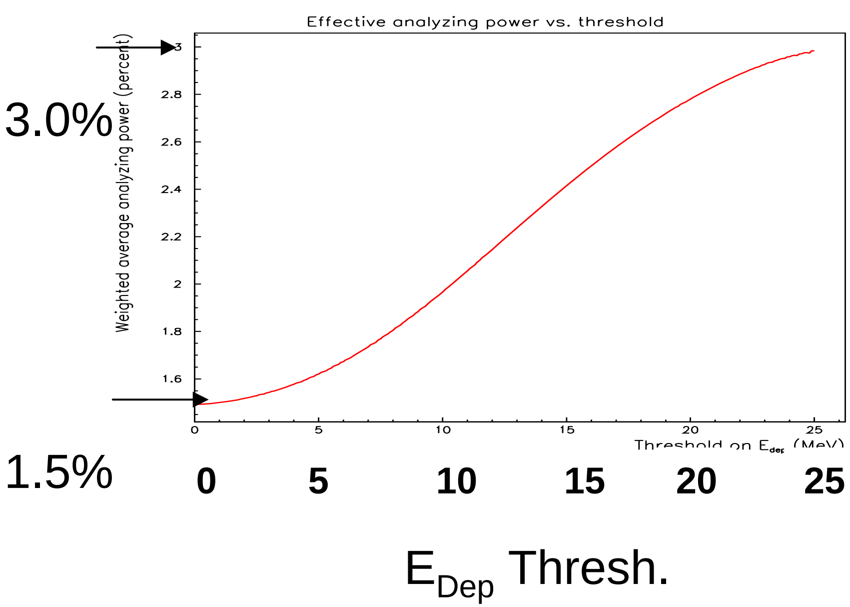
- Use Customized Flash ADC for Integration
  - Digitizes every 5 ns
  - Accumulators sum over 30ms helicity bins
  - Large pulse (bremsstrahlung) suppression
  - Built in live-time counter
  - About to receive:
    - Struck sis3320 FADC
    - Caen FADC



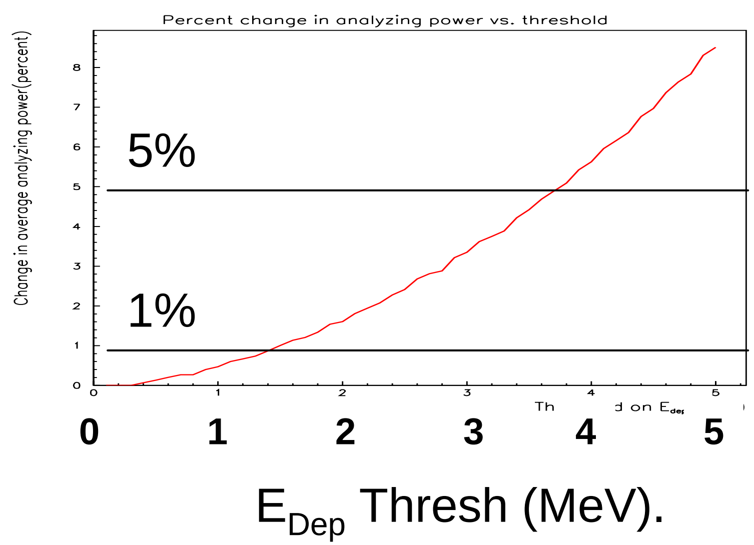
Need to **minimize** uncertainty in A_{ls}

Integration with low or no threshold reduces systematics

Analyzing Power of summed Deposited Energy as function of Deposited Energy Threshold

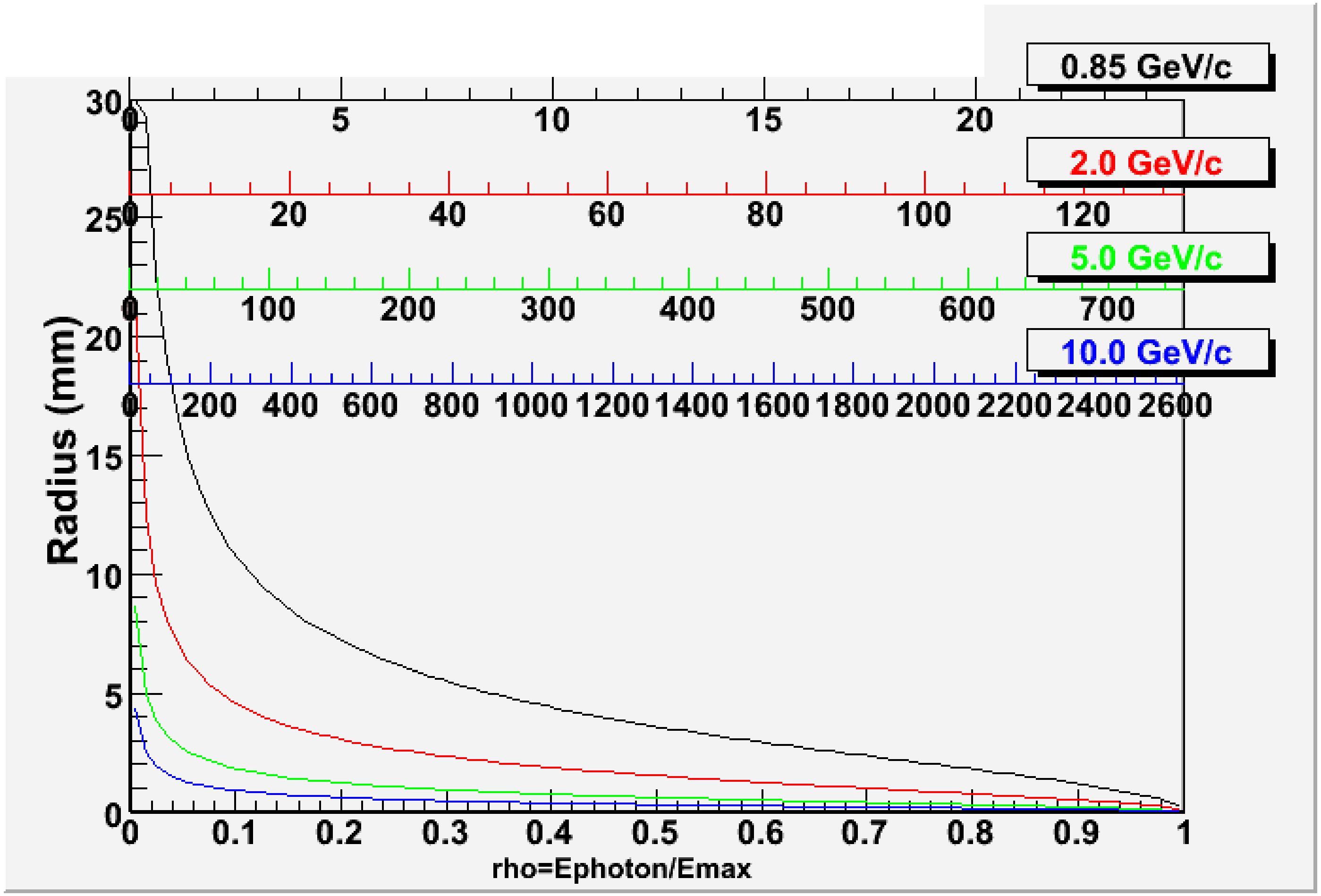


% Change in Analyzing Power



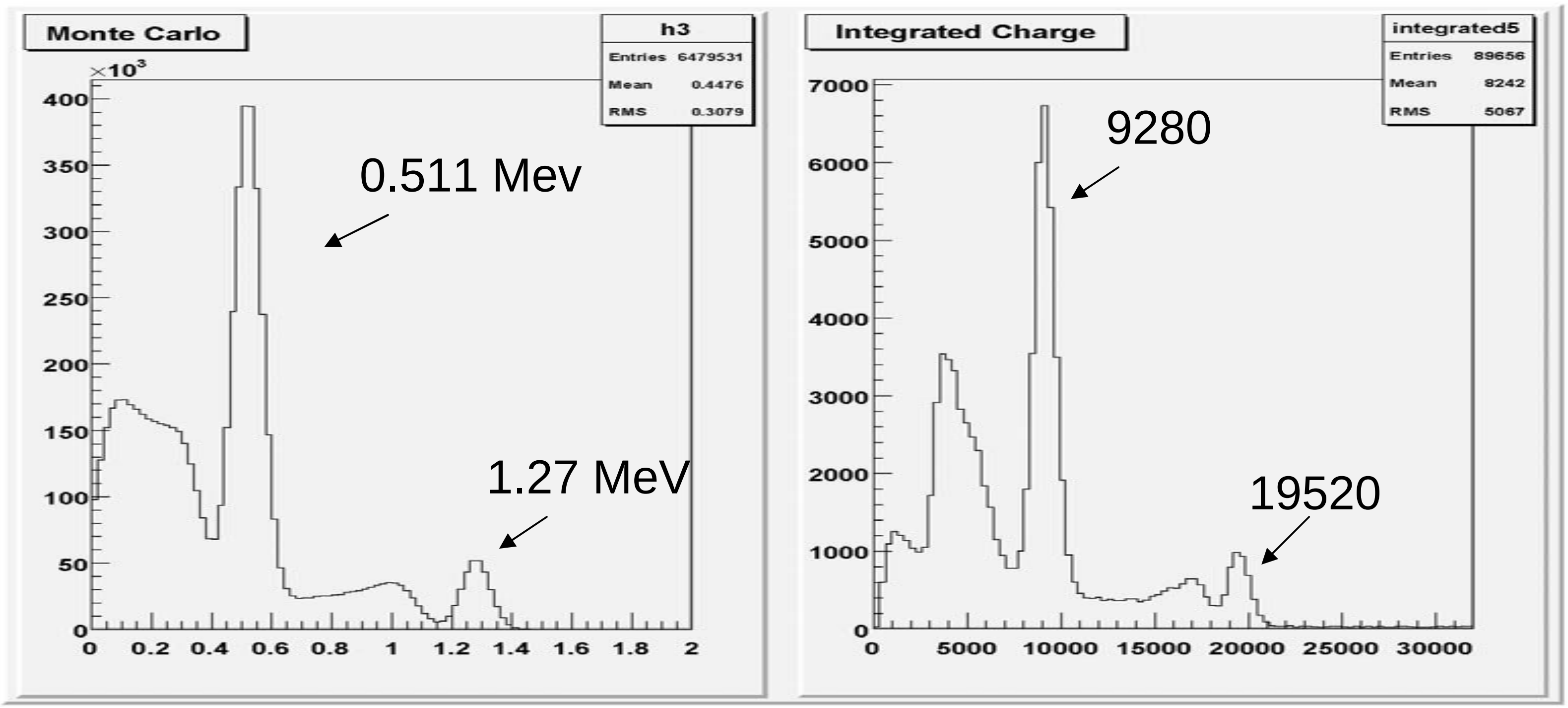
Need to model collimation correctly

Compton Photon Radius at 6 meters vs Photon Energy



Initial GSO response function studies

- ^{22}Na Source
- Sample 1 cm^3 GSO Crystal
- Struck FADC



GEANT4 SIMULATION
Energy Deposited
(+resolution smearing)

DATA
triggered FADC
Summing ~100 channels

Yossef Korang-Beheshti
Data and simulation

Statistics Considerations

Energy sum statistics for 1 macropulse (400 to 4000 events)

$$\frac{\sigma_{ESum}^2}{E_{Esum}^2} = \frac{\int_0^{E_m} dEE^2 \, dN/dE}{\left[\int_0^{E_m} dEE \, dN/dE\right]^2} = \frac{\int_0^{1_m} d\rho\rho^2 \, dN/d\rho}{\left[\int_0^{1_m} d\rho\rho \, dN/d\rho\right]^2}$$

$$\frac{\sigma_{Esum}}{E_{Esum}} = 1.2\frac{1}{\sqrt{N}}$$

For Compton scattering dN/dρ

$$\frac{\sigma_{Esum}}{E_{Esum}} = 1.2\frac{1}{\sqrt{4x10^3}} = 2\%.$$

For 33 ms period, 120 kHz

or

$$\frac{\sigma_{Esum}}{E_{Esum}} = 1.2\frac{1}{\sqrt{4x10^2}} = 6\%.$$

For 33 ms period, 12 kHz

Noise due to long integration period a problem?

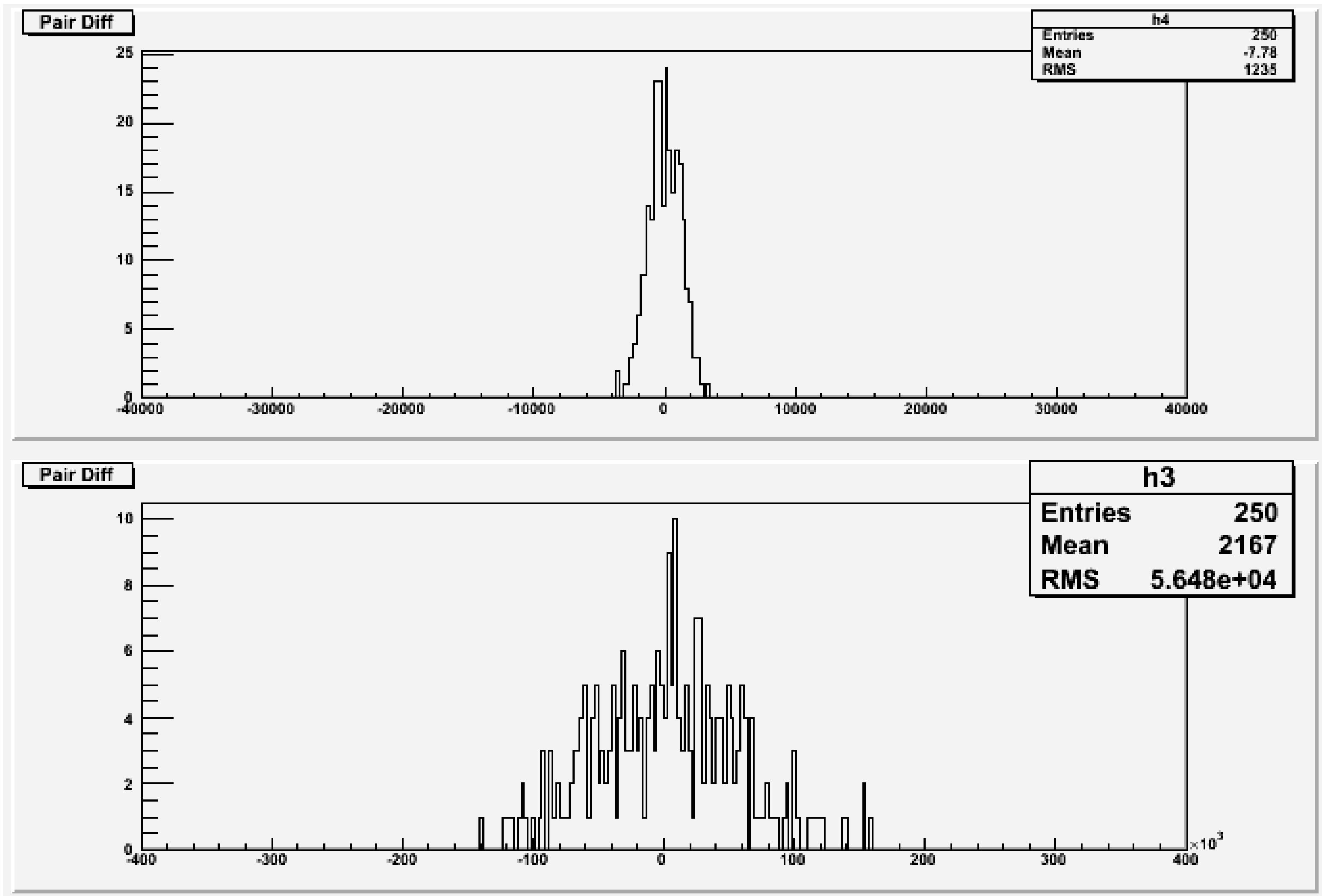
- 33 ms integration period
- 0.4 ms of signal at 120 kHz, 100 ns per pulse

CMU Tests of FADC Pedestal Width

- FADC runs at 5ns per sample
- Sum $6x10^6$ samples for 1 integration period in VME crate
- Plot pedestals

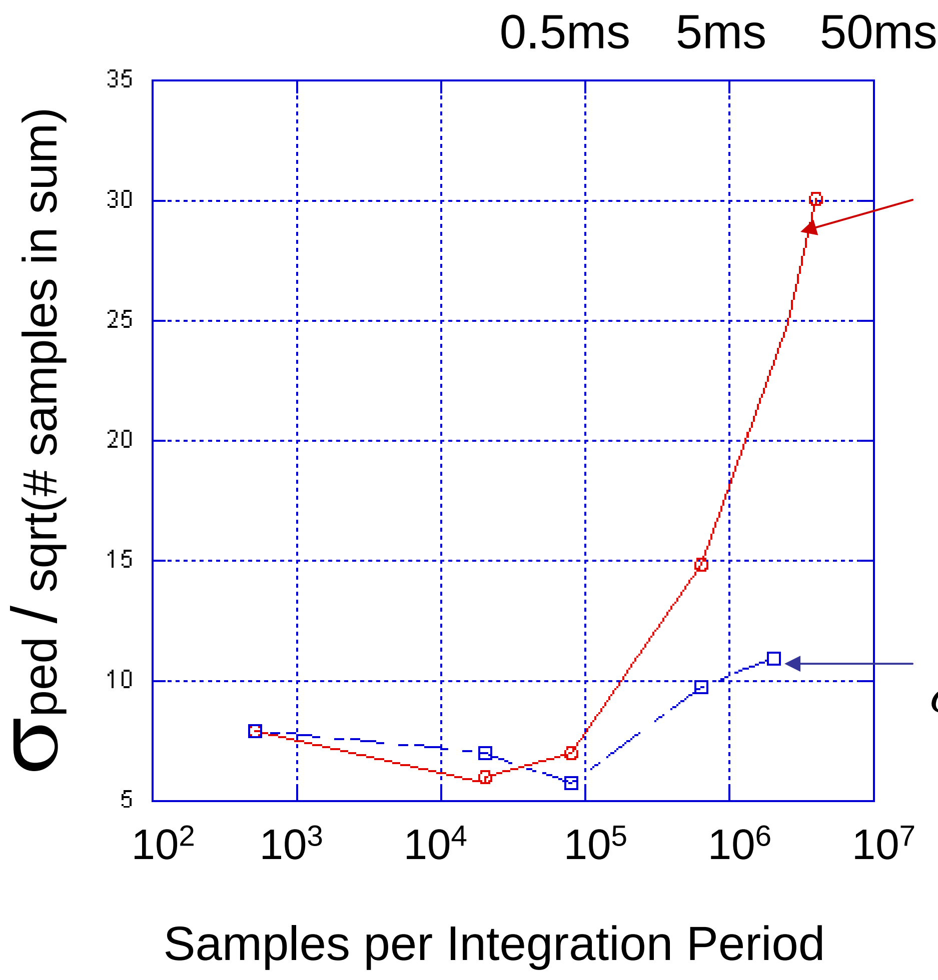
Some Problems

- Only first $4x10^6$ samples good (memory mapping problem?)
- 9 seconds to read across VME backplane
- First integration samples funny?
- Odd behavior if extra “start” signals
- “Reflection like” glitch ~500 ns after signal



Pair Diff
h4
Entries 250
Mean -7.78
RMS 1235
25
20
15
10
5
0
-40000
-30000
-20000
-10000
0
10000
20000
30000
40000
Pair Diff
h3
Entries 250
Mean 2167
RMS 5.648e+04
10
8
6
4
2
0
-400
-300
-200
-100
0
100
200
300
400
×10^3

Pedestal widths by differences of two integration sums



2 consecutive macropulses
(~ 9 seconds part)

Both sums from same
Macropulse
(~ 10 ms apart)

$$\sigma_{ped} \approx 10\sqrt{N_{\text{integrated}}}$$

$$= 2.5\times10^4 \text{ for } 33\text{ms}$$

Statistics Considerations

Pedestal noise small compared to signal statistics?

- *Average Signal per Compton Photon*
  - *Is*= 8200 rau (Raw ADC Units)

    (PMT HV adjusted for Compton Photons on FADC scale)

- Average Integrated Signal per Macropulse
  - S= $3.3x10^6$ to $3.3x10^7$ (12 KHz to 120 kHz)

Pedestal noise small compared to signal statistics?

• Pedestal Width Noise over Integrated Signal

$$\frac{\sigma_{ped}}{s} = \frac{2.5x10^4}{s} = 0.7\% \text{ to } 0.07\%$$ (12 to 120 kHz)

• Compare to Signal Statistics

$$\frac{\sigma_{Esum}}{E_{Esum}} = 6\% \text{ to } 2\%.$$

Fluctuations due to pedestal width OK if preliminary measurements are correct