Electron Polarimetry at MIT Bates

T. Zwart, M. Farkhondeh, W. Franklin, E. Tsentalovich,
MIT Bates Accelerator Center

Outline:

Polarized Source

Moller Polarimeter

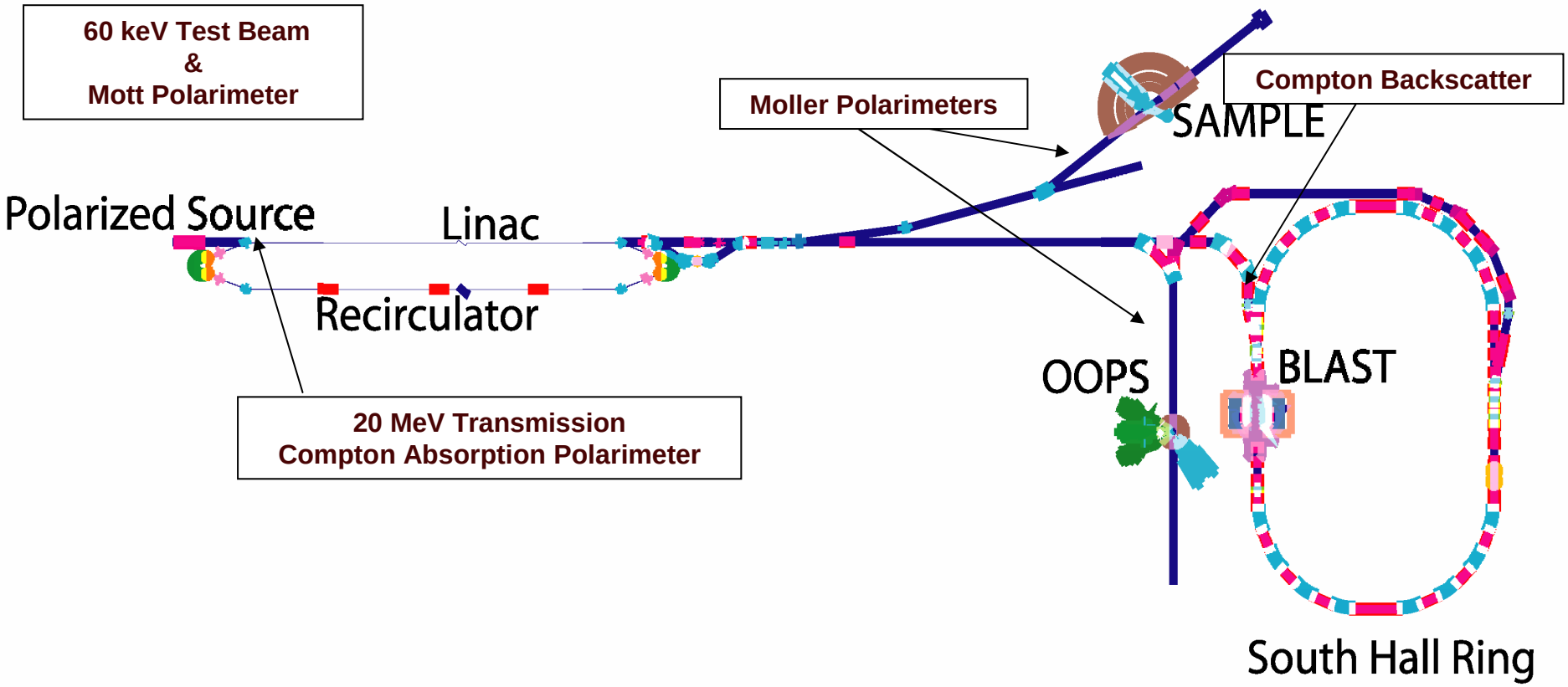
Mott Polarimeter

Compton Absorption (Transmission) Polarimeter

Laser Backscattering Compton Polarimeter

Calibration of a 5 MeV Transmission Polarimeter

MIT Bates Accelerator Center



Accurate Polarimetry

Accurate Polarimetry Benefits From:

1) Stable Calibrated Sources

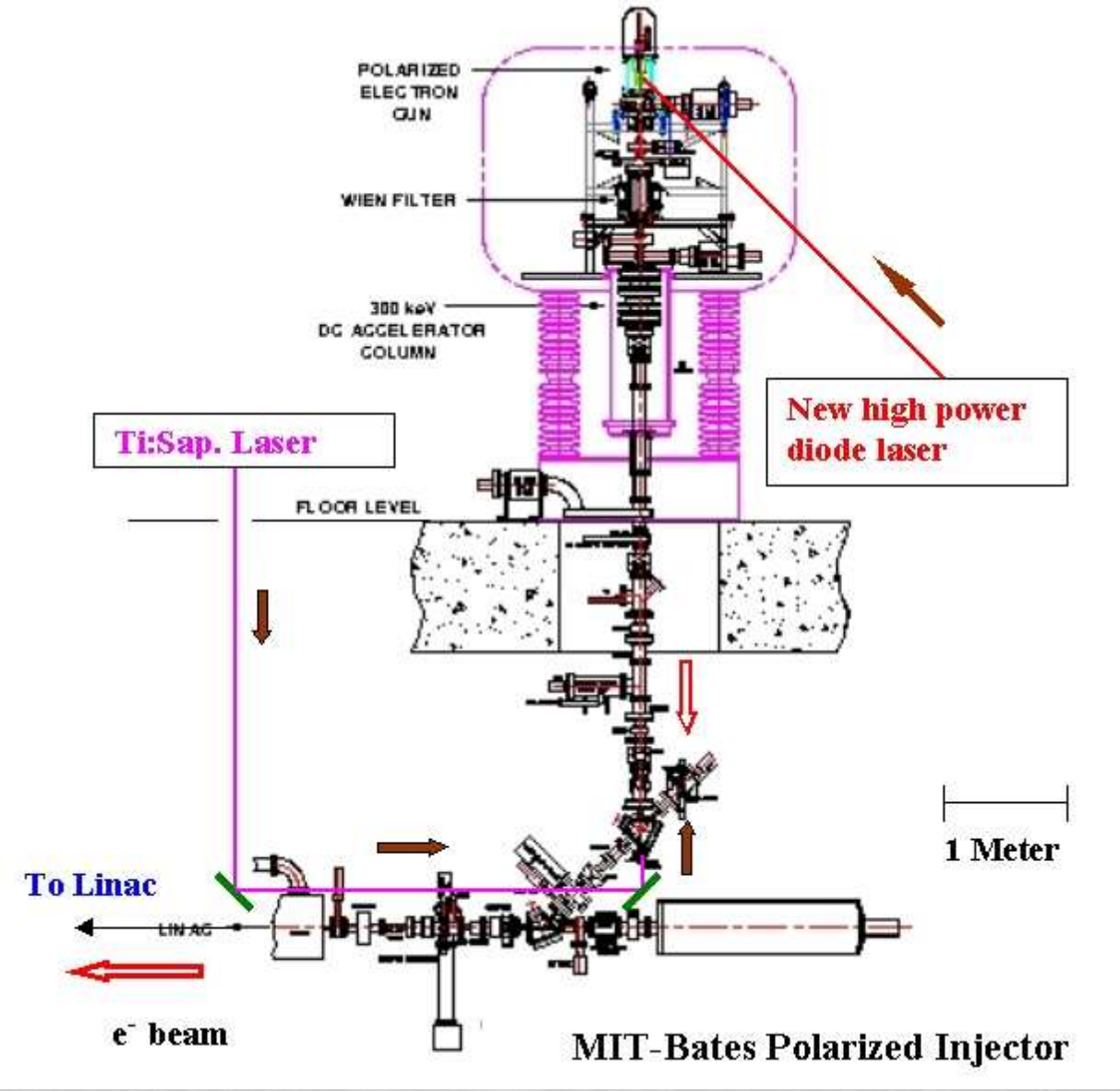
2) Multiple Polarimeters operating Simultaneously

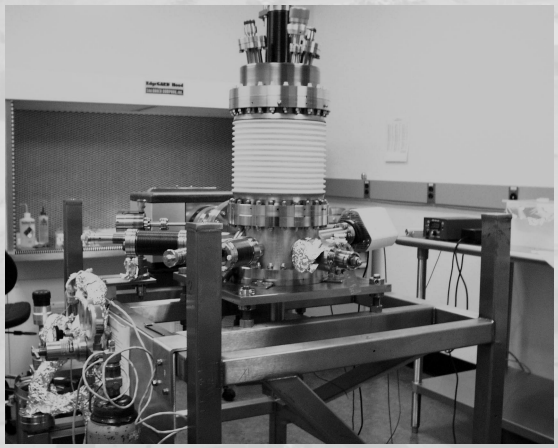
3) Simple Instruments

4) “Controlled” Systematics

MIT Bates Polarized Source

M. Farkhondeh, W. Franklin, E. Ihloff, E. Tsentalovich

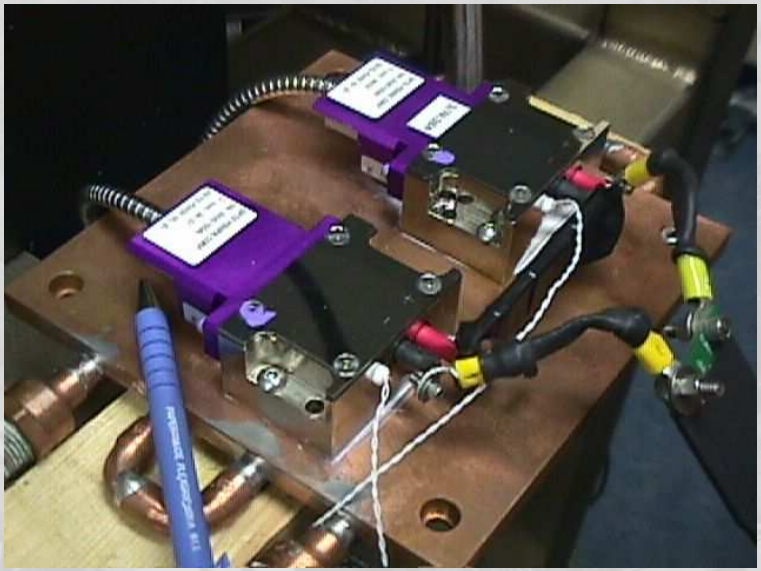


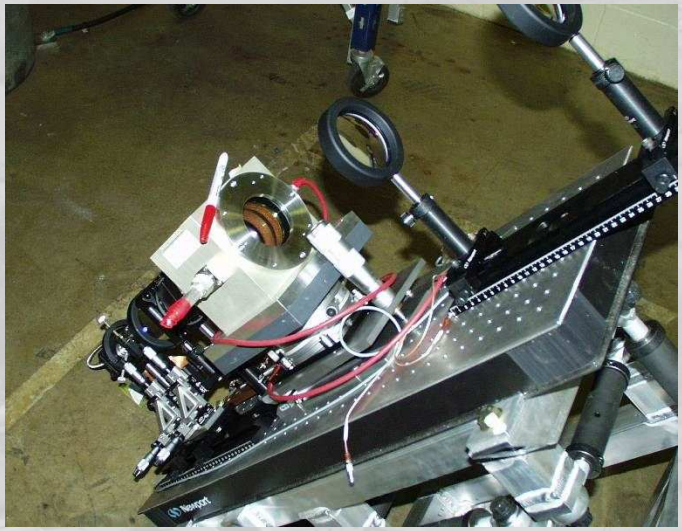


Stan Kowalski

- Three identical guns:
  - Injector
  - Backup
  - Test Setup
- 4 days to interchange.

High Power Diode Laser Provides a Very Stable Beam





Fiber-coupled diode array lasers

- **Wavelength:** 808± 3 nm (fixed)
- **Emittance:** 200 mm.mr (short working distance)
- **Power:** 150 W @ 1% DF, 60 W CW
- **Stability:** Better than Ti:Sapphire laser by > 10
- **Need large diameter optics (75 diameter HPC),**

Moller Polarimeters

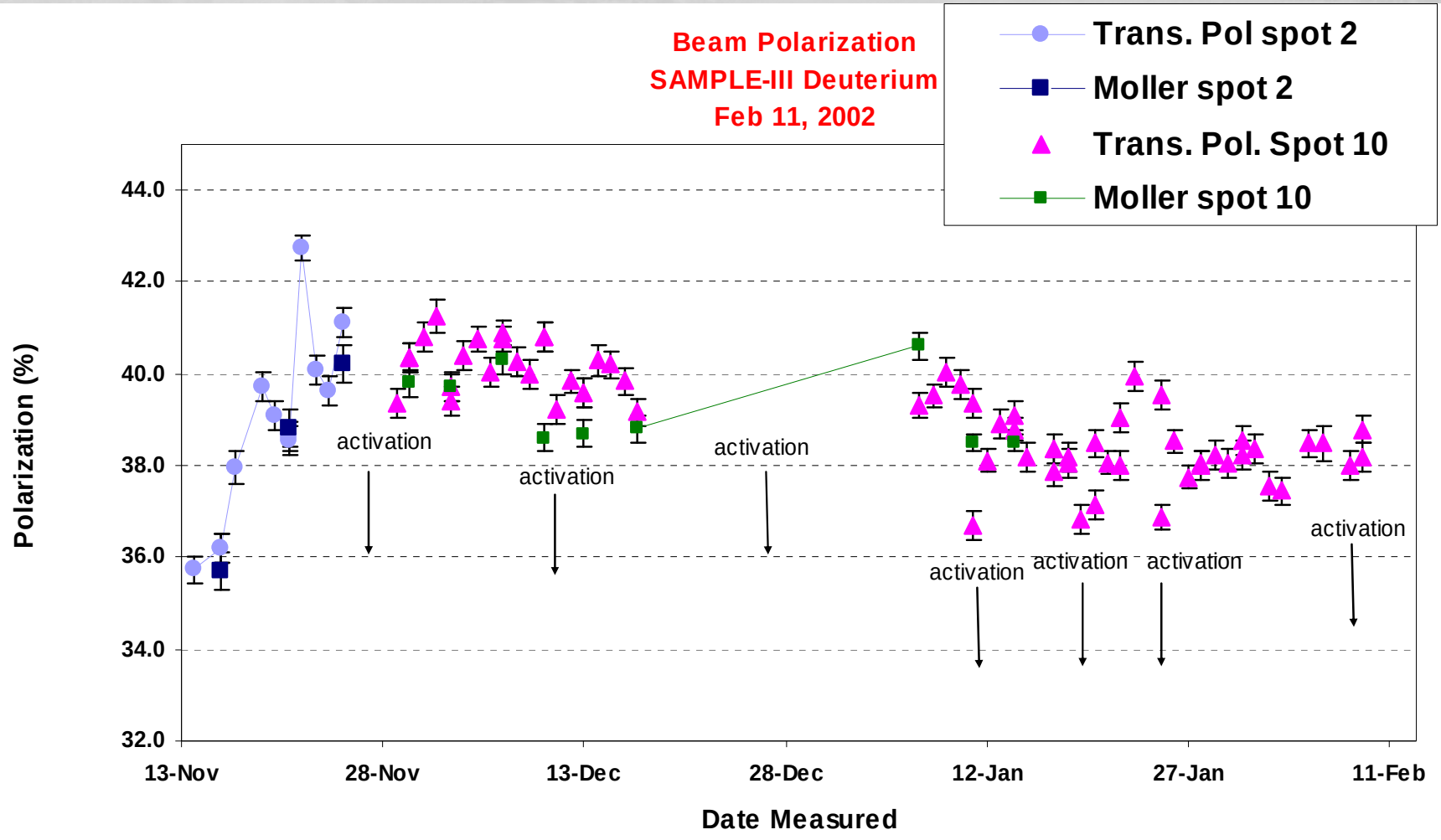
Two Fixed Target Moller Polarimeters 100-1000 MeV
Dipole Dipole Single Arm(SAMPLE)
Quadrupole (FPP, OOPS)

Reliable, Stable

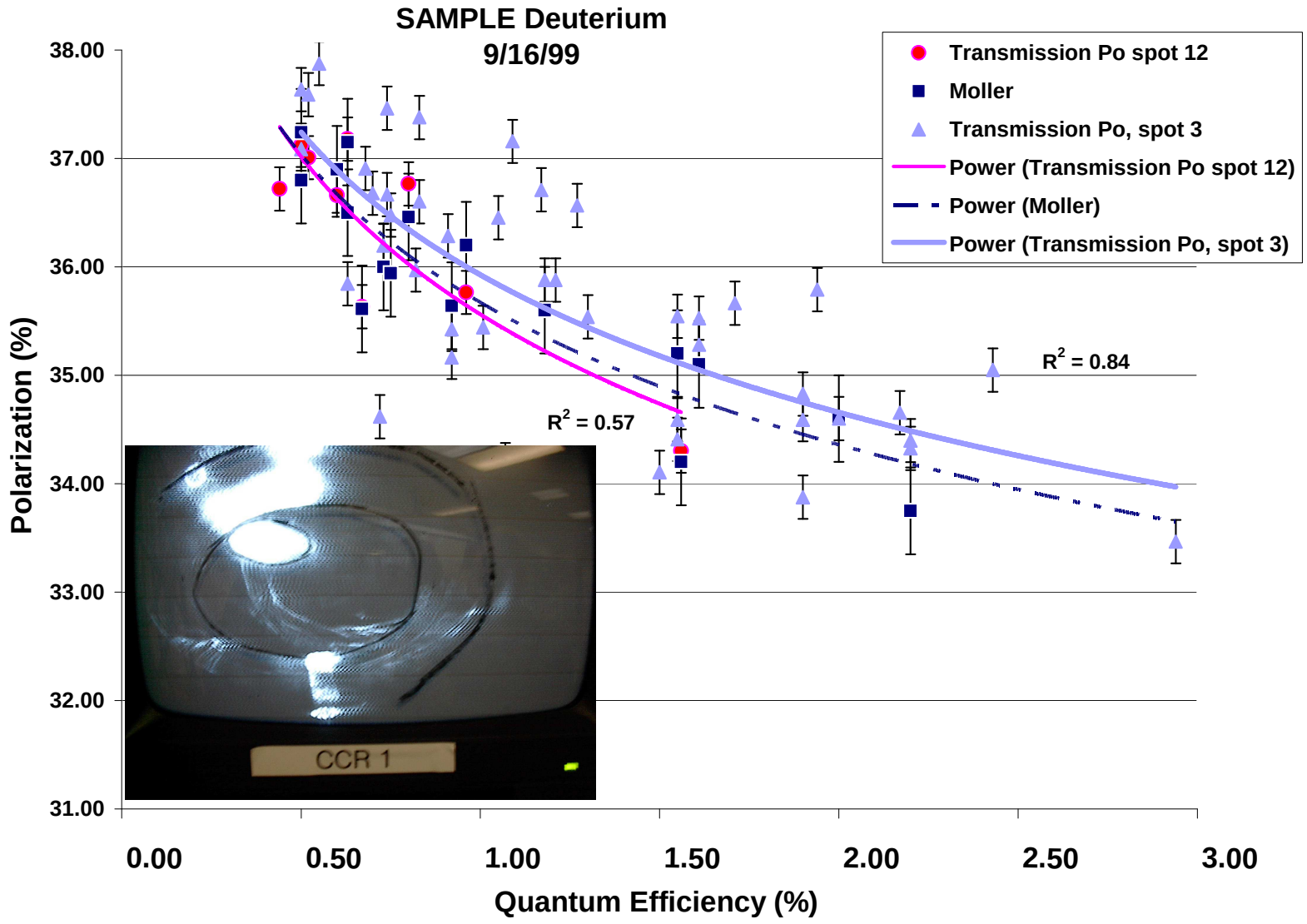
4 uA Beam Current

Systematic Errors Dominated by Foil Polarization
$\Delta P_e/P_e = 3\%$

Not Sensitive to Levchuk Effect due to relatively "poor" resoltuion in e'.


Beam Polarization
SAMPLE-III Deuterium
Feb 11, 2002
Trans. Pol spot 2
Moller spot 2
Trans. Pol. Spot 10
Moller spot 10
Polarization (%)
44.0
42.0
40.0
38.0
36.0
34.0
32.0
activation
activation
activation
activation
activation
activation
activation
13-Nov
28-Nov
13-Dec
28-Dec
12-Jan
27-Jan
11-Feb
Date Measured

Polarization Depends on QE & Spot Location

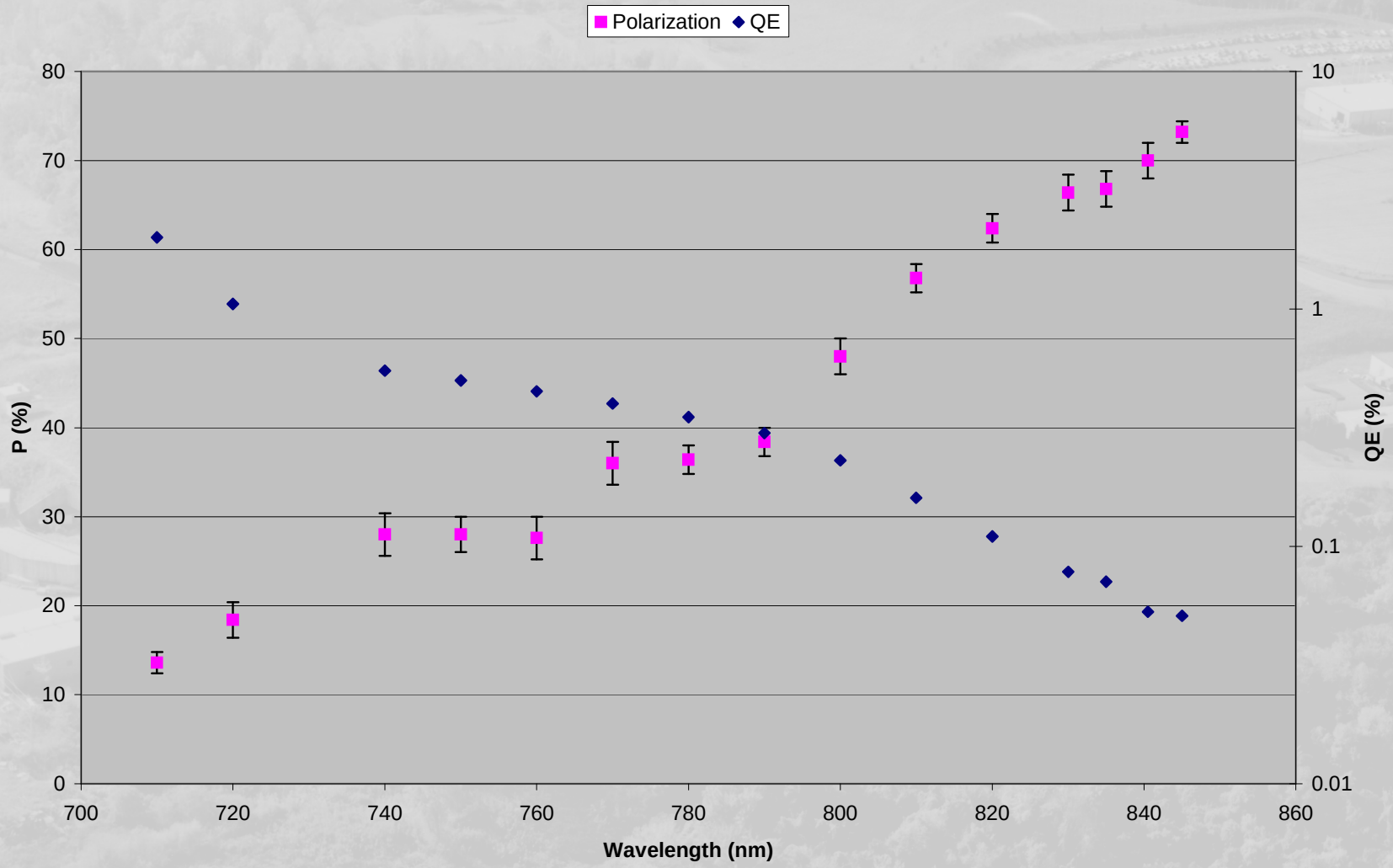


60 keV Beamline & Mott Polarimeter

M. Farkhondeh, W. Franklin, E. Ihloff, E. Tsentalovich

1. Independent of main accelerator
2. Qualifies all guns before installation on accelerator
3. Allows R&D on:
   - High P Cathodes
   - Laser Systems
   - Precision Polarimetry

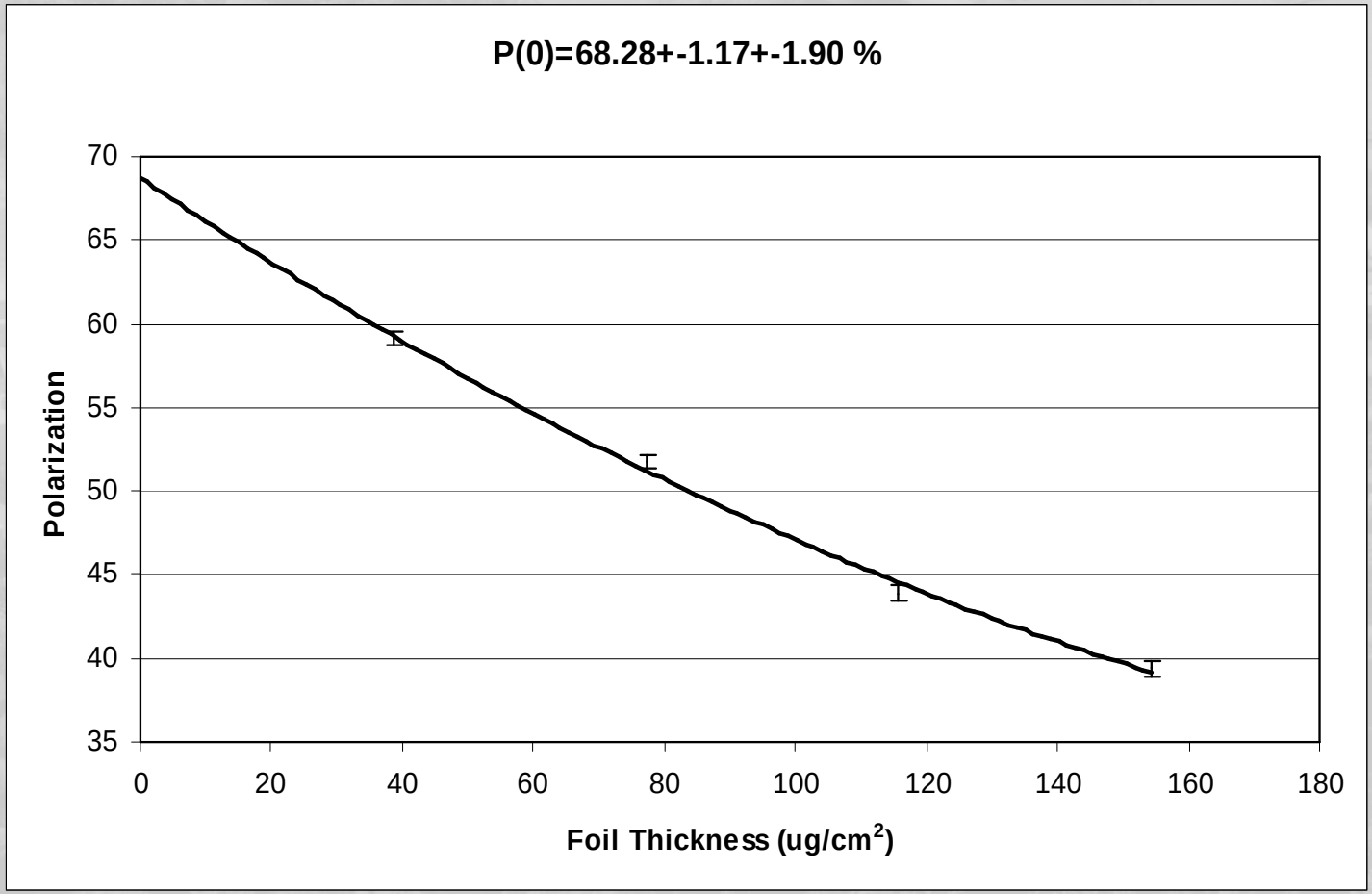
Polarization is Wavelength Dependent



Temperature Coefficient: 0.5 nm/°C
Indium Layer Applied Between Photocathode and Holder

Mott Polarimeter Extrapolation to Zero Foil Thickness

E. Tsentalovich

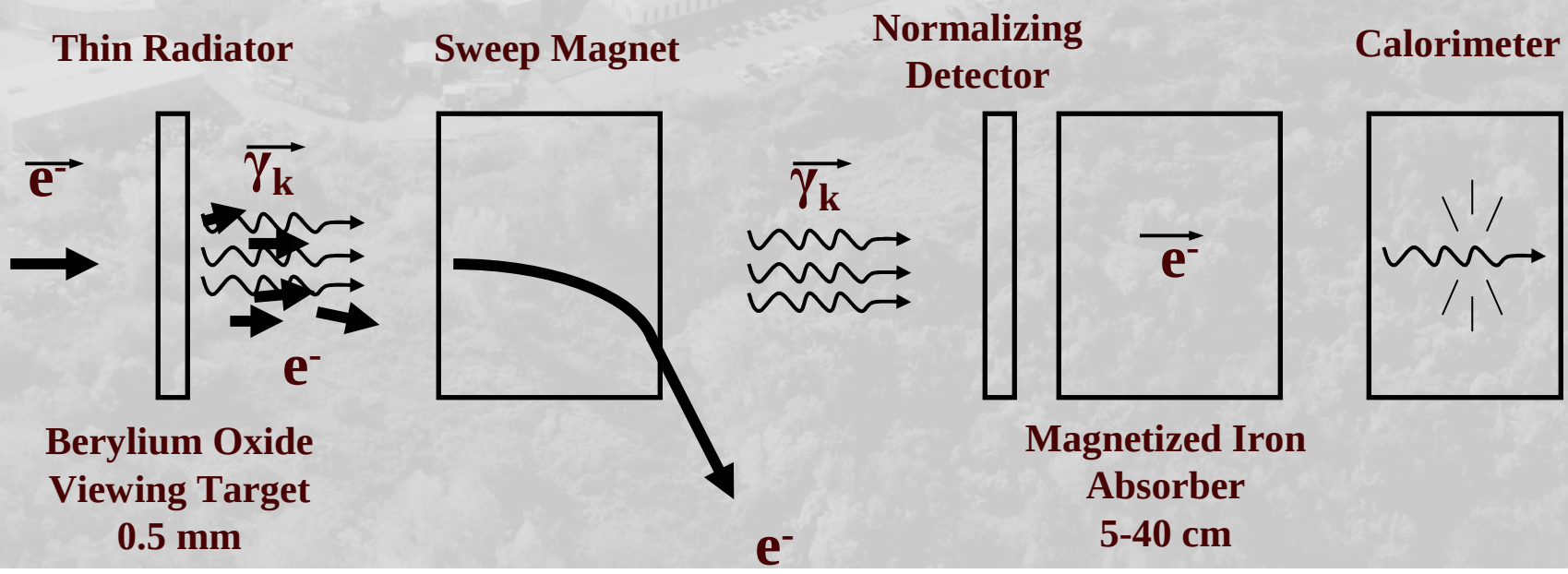


Systematic Error is Dominated by Uncertainty in Sherman Function

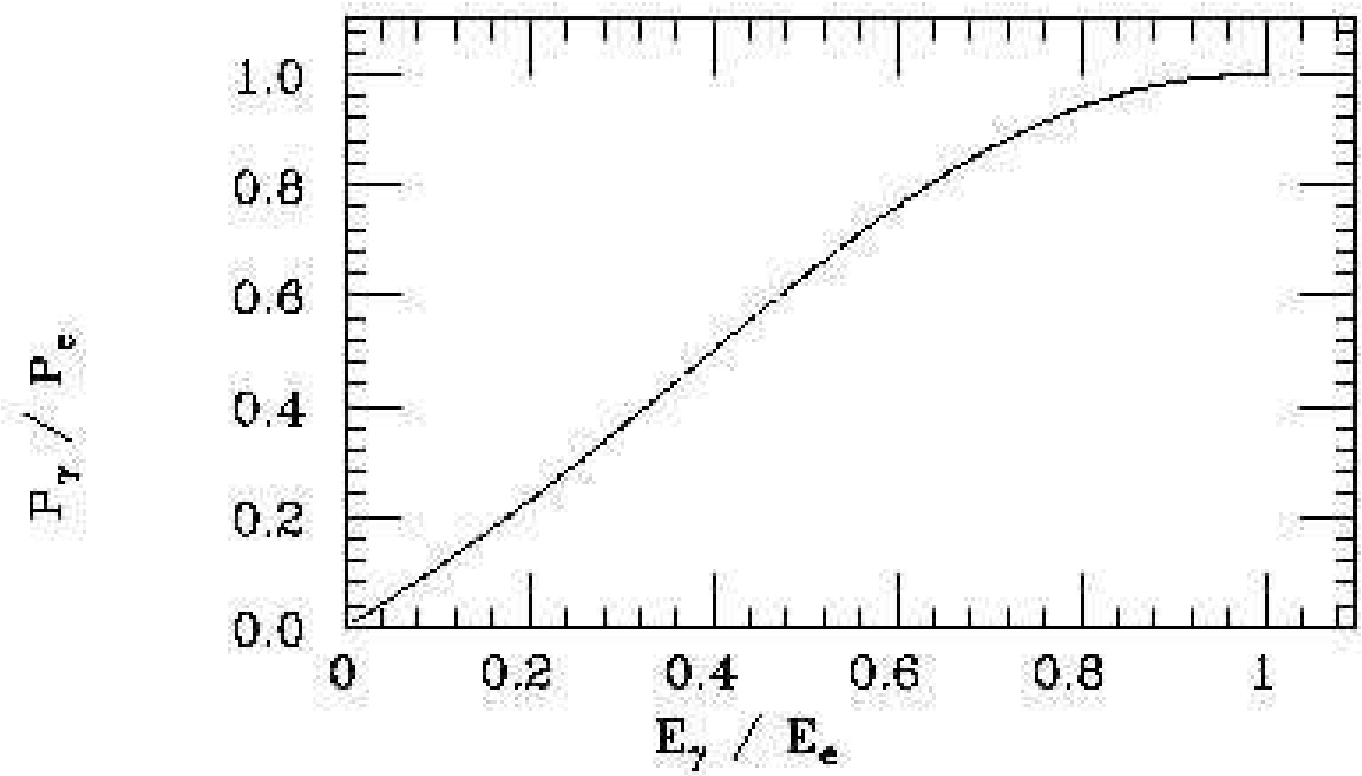
Transmission Polarimeter

1. Make Polarized Photons (Bremsstrahlung from $\vec{e}$ on thin Radiator)
2. Remove Electrons from Shower
3. Absorb Polarized Photons with Spin Dependent Cross Section (Magnetized Iron Absorber)
4. Measure Spin Dependent Yield in Downstream Calorimeter
5. Calibrate Analyzing Power Against "Well Known" Polarimeter (Mott, Compton, Møller)

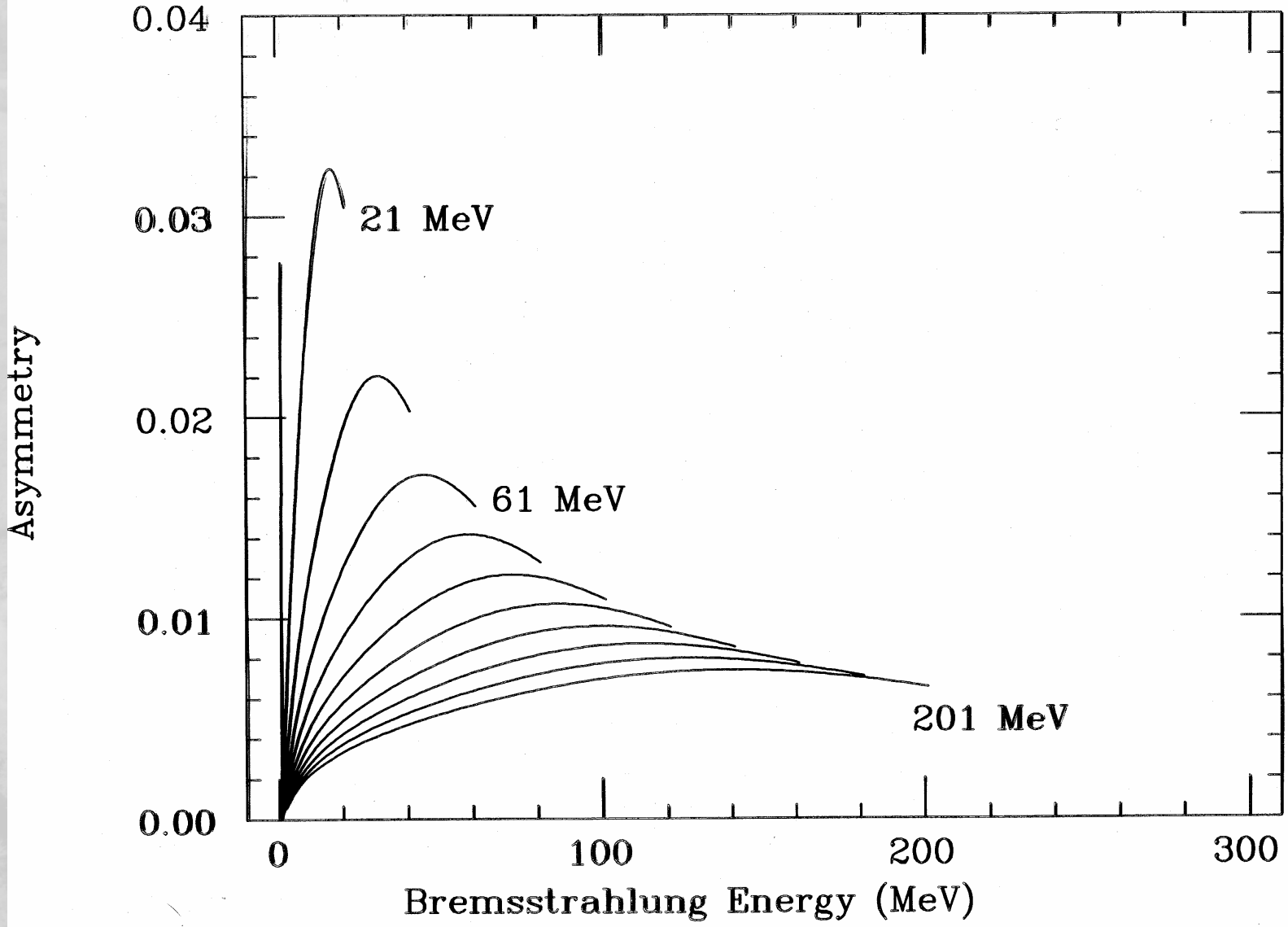
J. Bellanca and R. Wilson in *Parity Violation in Electron Scattering* edited by E.J. Beise and R.D. McKeown (World Scientific, New Jersey, 1990) p 111



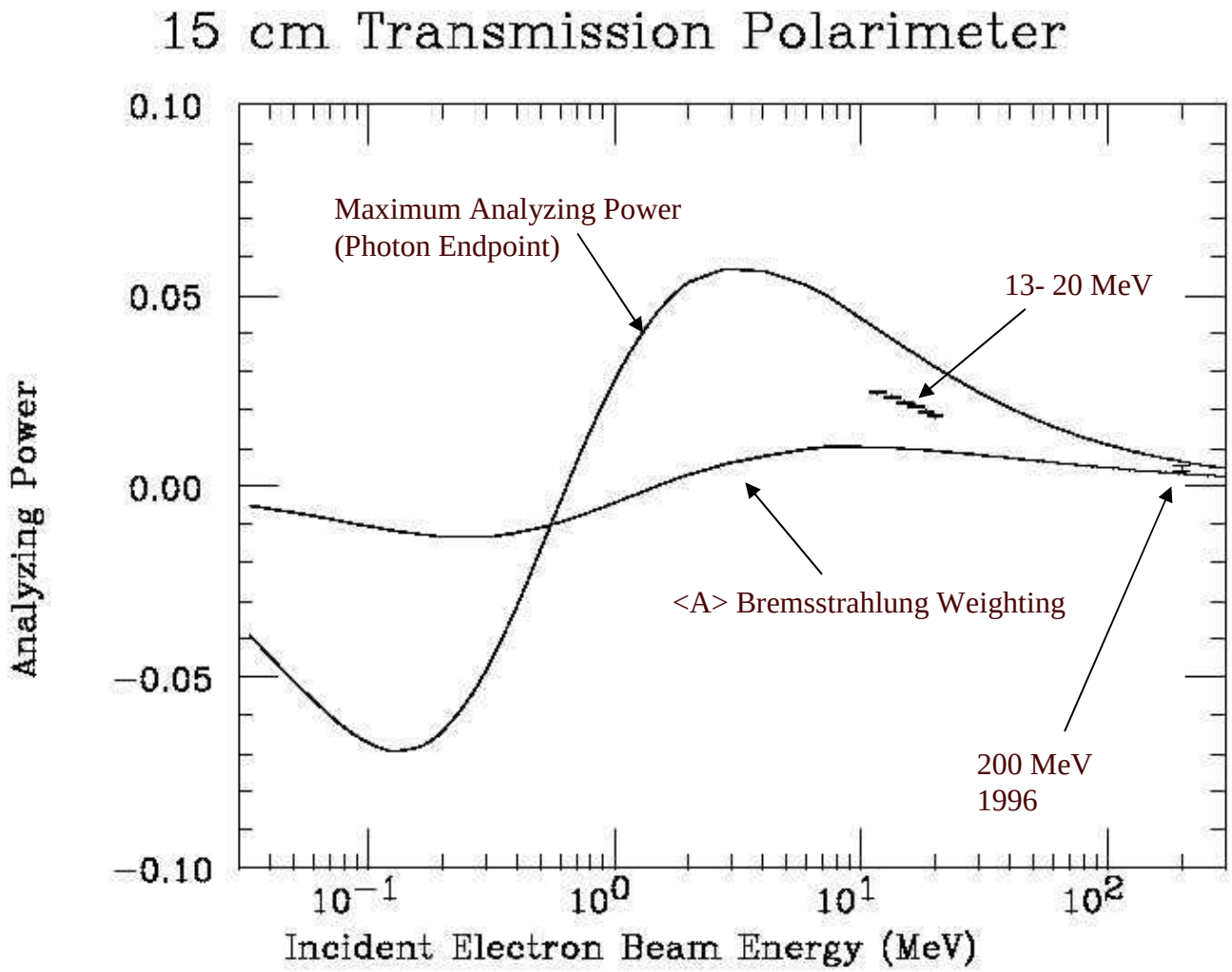
Bremsstrahlung Polarization



Transmission Asymmetry



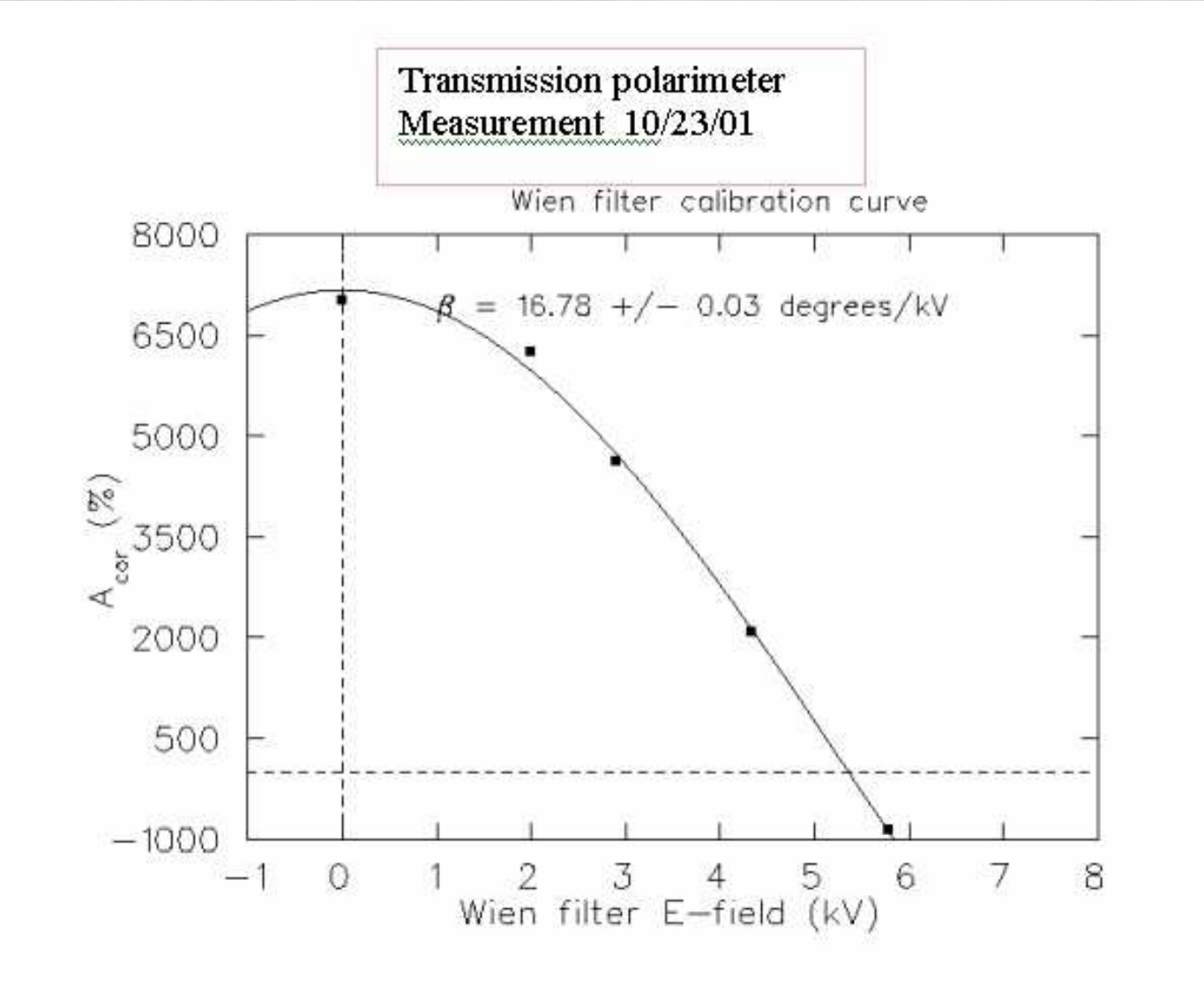
Trans. Polarimeter Analayzing Power



20 MeV Transmission Polarimeter Absorption Magnet

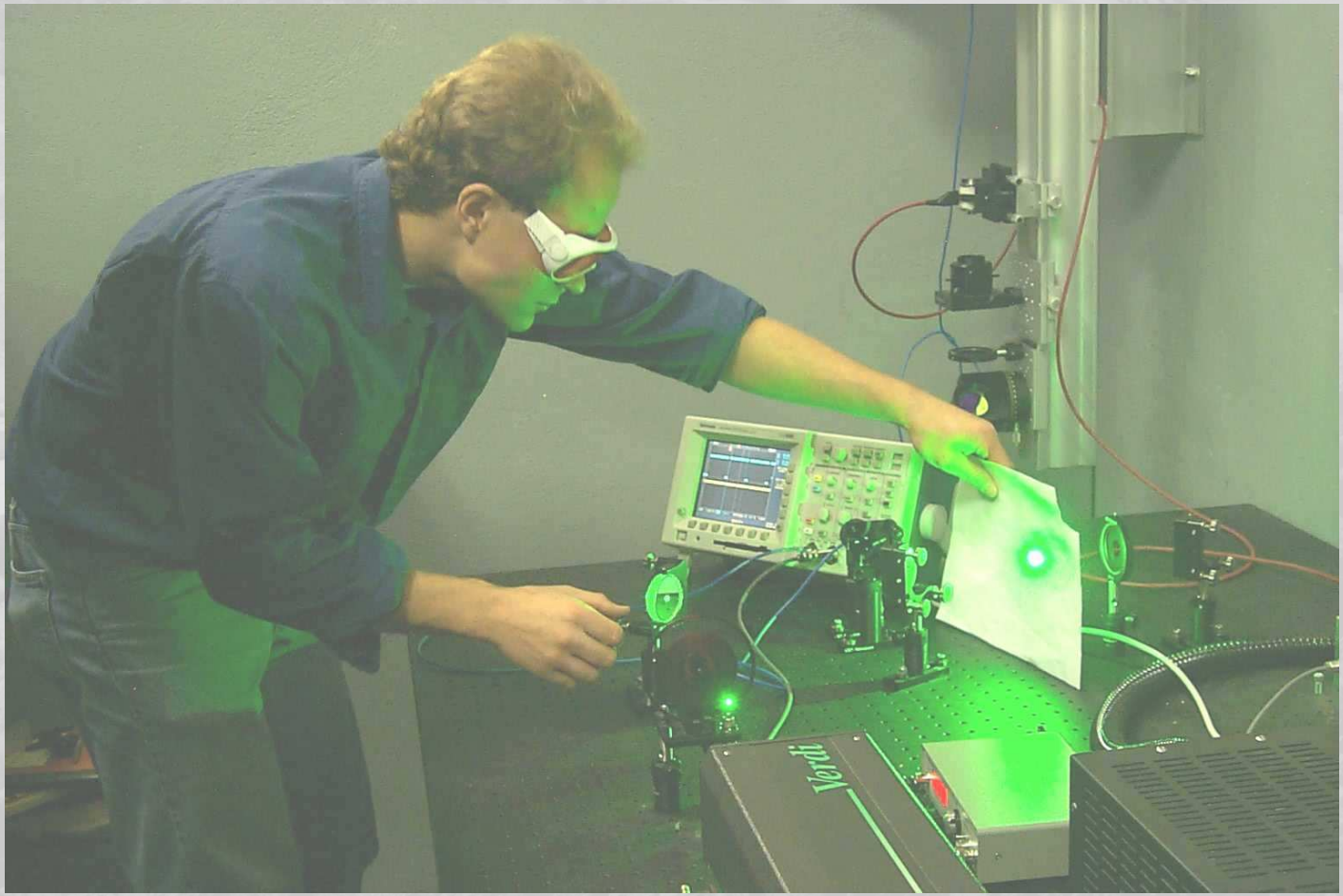
Wien Filter Calibration

High FOM ($NA^{2)}$ enables accurate establishment of polarization transport



Laser Back-Scattering Compton Polarimeter

W. Franklin, T. Akdogan, E. Booth, D. Dutta, M. Farkhondeh,
M. Hurwitz, E. Ihloff, J. Matthews, E. Tsentalovich, T. Zwart

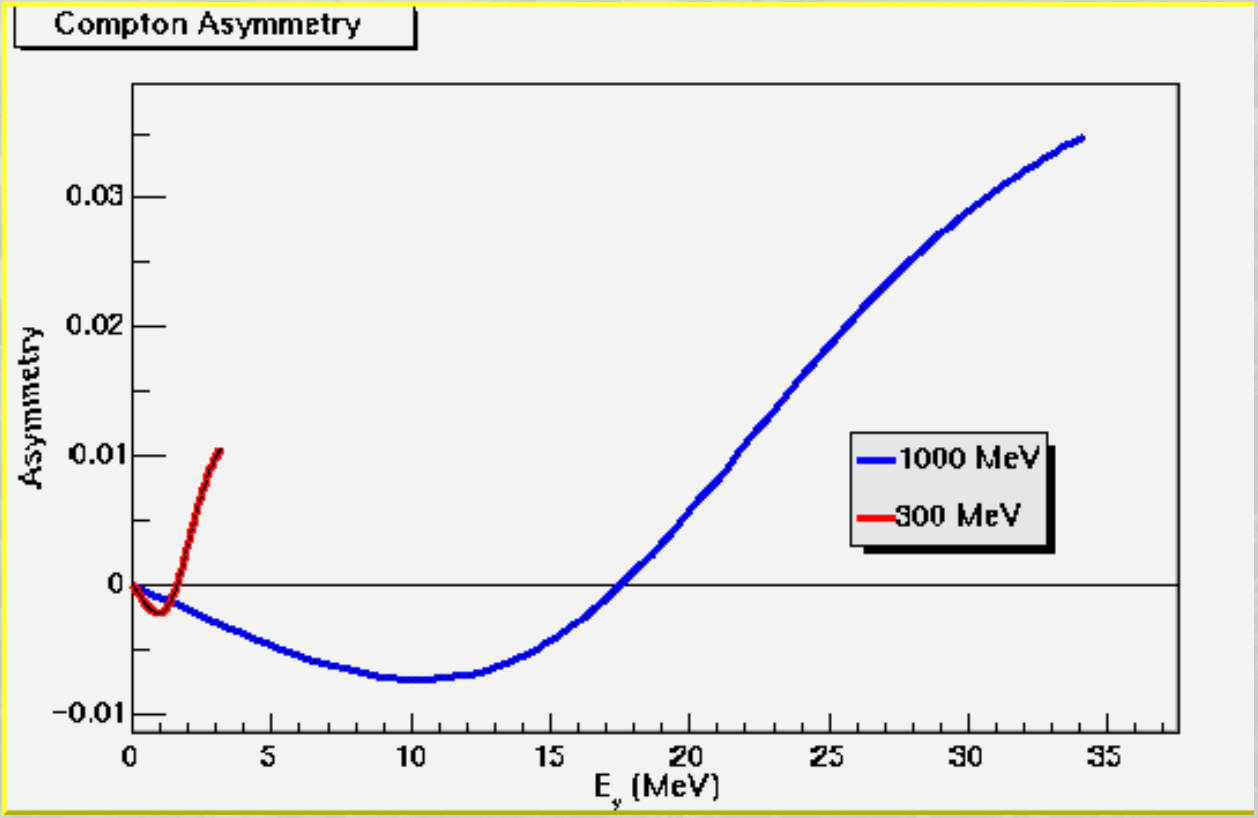


5 W Diode Pumped 532 nm VERDI Laser

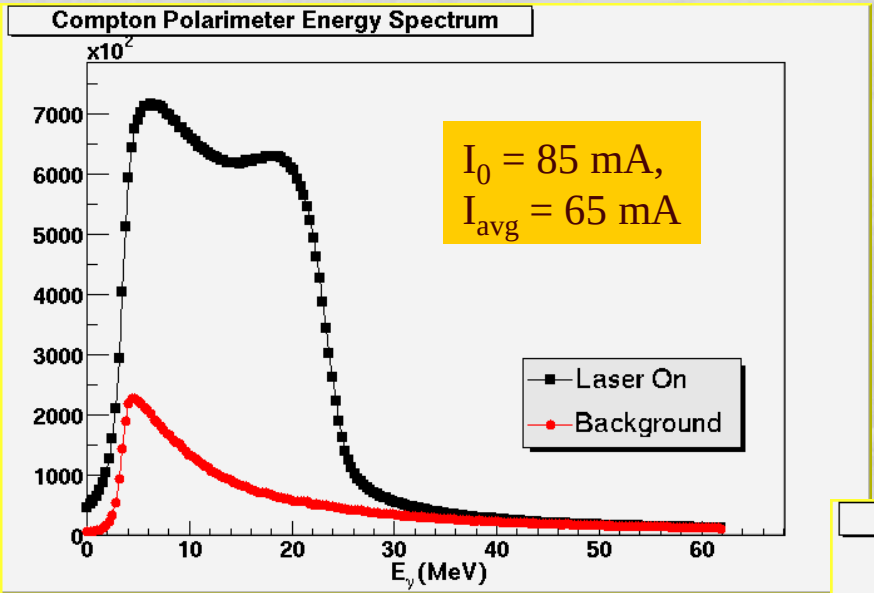
Compton Polarimeter

Longitudinal Polarization –

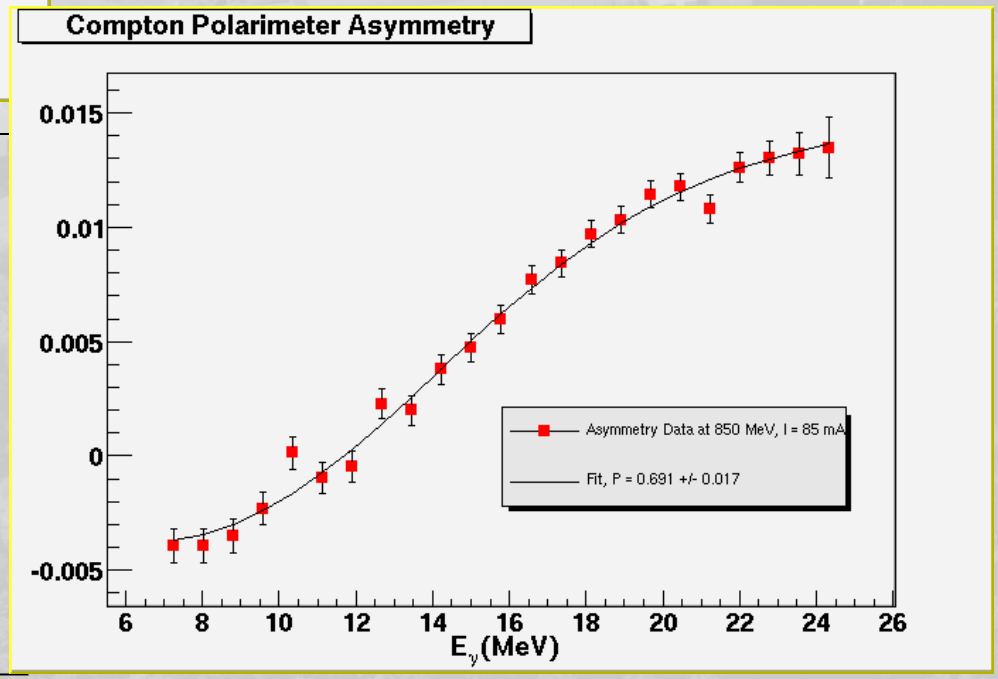
- Longitudinal Polarization 300 MeV – 1000 MeV
- Similar to NIKHEF AmPS Polarimeter. (Igor Passchier)
- High Current Operation (~100 mA)
- Small Analyzing Power at Lower Energy



Compton Polarimeter Spectra



- Polarization measurements made at currents up to 130 mA. Signal to background ratio worsens at high currents but still tractable
- Variable Thickness Stainless Steel Absorbers: 1”, 2”, 3”
- No Pileup Systematic
- Systematics due to Absorber (<3%)



- Polarization about 0.70 typical
- Statistical precision of measurements governed mostly by signal-to-background ratio. Typical precision of 1-2% per hour.
- Systematic errors estimated at 5% level presently. Working on reducing these through improved analysis of energy spectrum

Systematic Error Estimation

- Small analyzing power makes systematic error reduction crucial
- Need accurate modeling of shape and magnitude of analyzing power and good energy calibration for calorimeter ($\Delta P \sim 0.03$)
  - Some dependence on beam intensity and geometric configuration
- Laser circular polarization appears to be stable ($\Delta P < 0.01$)
- Modeling of analyzing power (0.02)
- Uncertainty in spin precession between polarimeter and BLAST ($\Delta P \sim 0.01$)
- Polarization Induced Transport Asymmetry (0.10 for single electron polarization, 0.02 for average polarization)
- Normalization technique for energy spectra (0.02)
- Transverse polarization ($\Delta P < 0.01$)

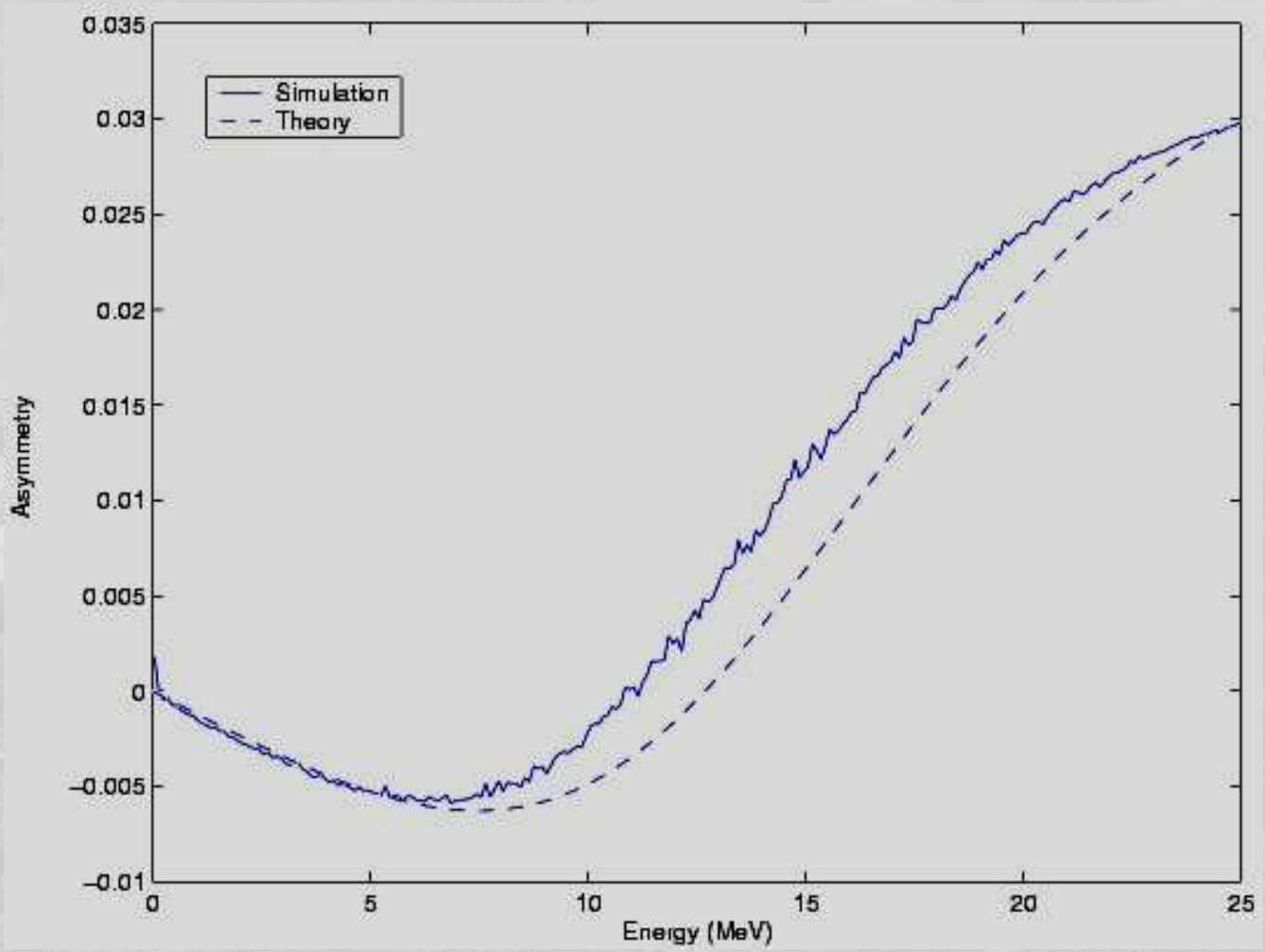
Total systematic error in average beam polarization estimated at 0.05. Working to reduce these numbers, but sufficient for initial set of BLAST experiments. Comparable to systematics with NIKHEF Compton Polarimeter.

I. Passchier et al, NIM A414, 446 (2000)

Source of systematic error	ΔP_e
E_γ calibration	0.022
P_{laser}	0.013
$\alpha_{3\gamma}$ parametrisation	0.004
E_e	0.003
Energy spectrum shift	0.001
Luminosity asymmetry	0.001
Total	0.027

Geant Simulation of Calorimeter Response

M. Hurwitz



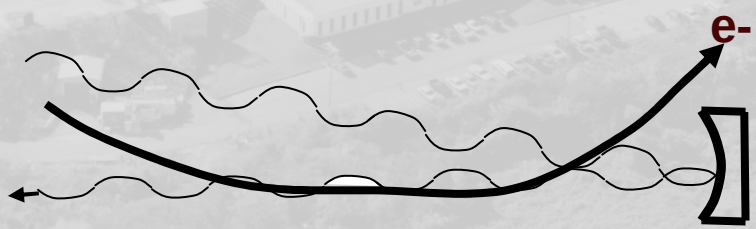
Things we might do Differently

Introduce laser from upstream (E. Ihloff)

Preserves near normal Incidence on mirror

Polarization transport greatly simplified

Similar to solution for polarized injector
(Kowalski, Beck)



Stored beam time structure is compatible w/ use of waveplates rather than Pockels cells to prepare circular polarization.

Calibrated Sources

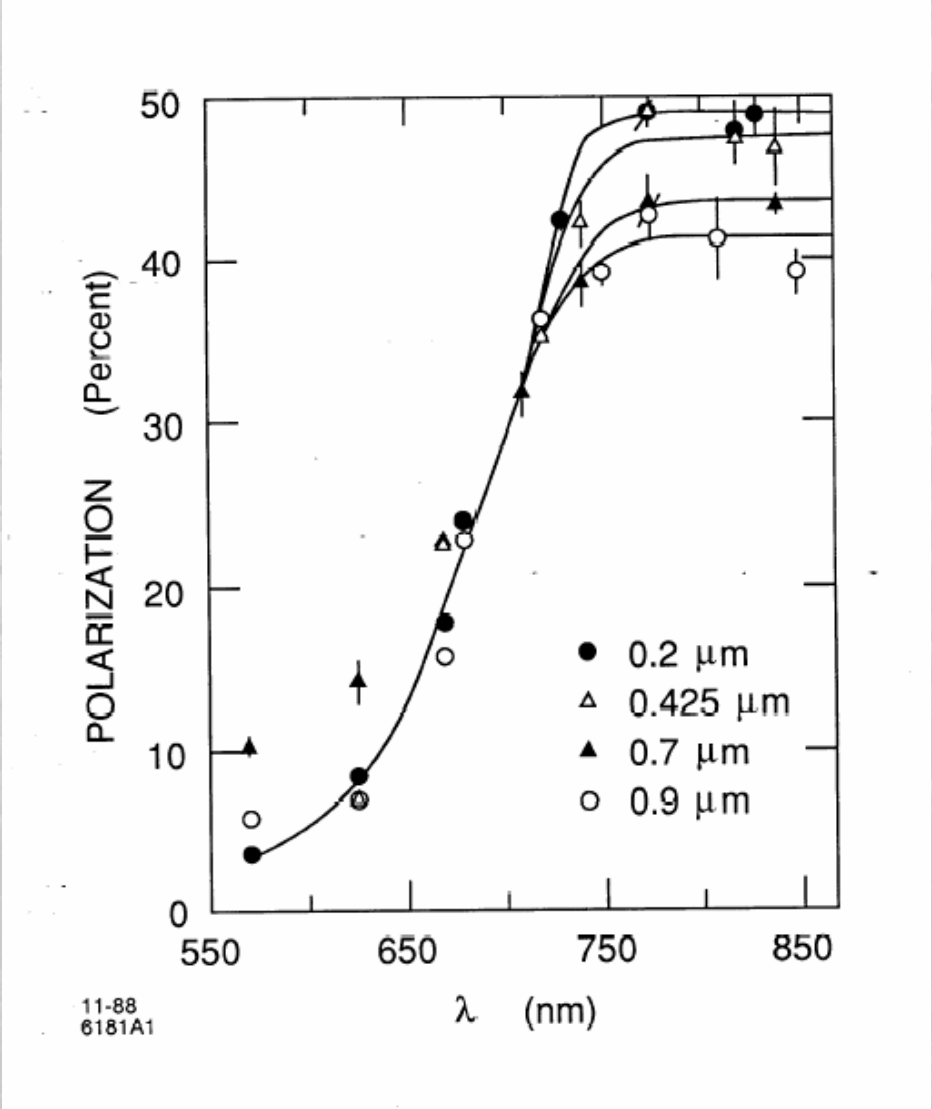
Ideal Calibration Source would be 100% Polarized e-. Delivered at operating current.

Not yet possible.

But P_e=50%?

Thin Bulk GaAs (100-200 nm)

More recent work has not confirmed this. (Sinclair et. al.)



T. Maruyama et. al. Appl. Phys. Lett. 55: 1686, (1989)

Transmission Polarimeter Calibration

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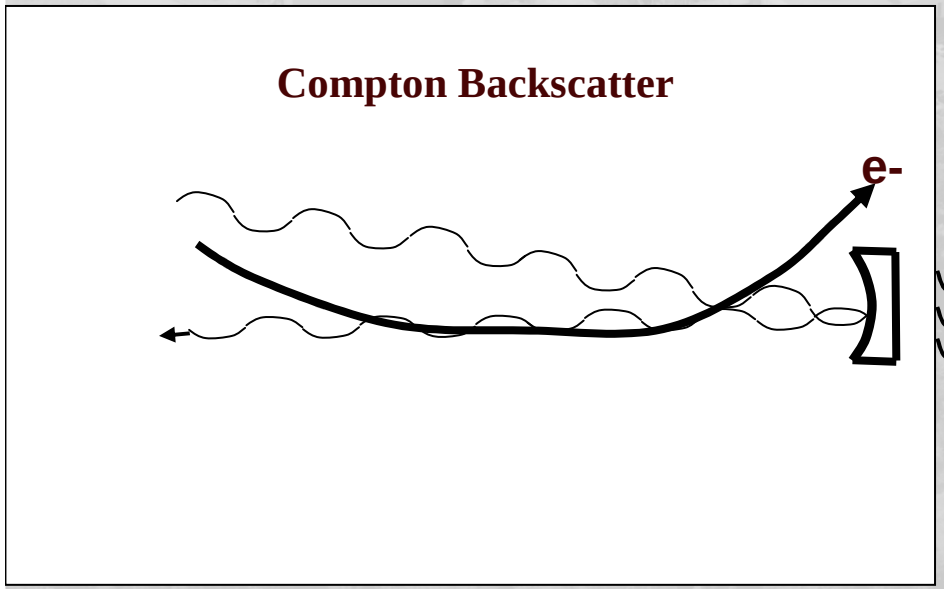
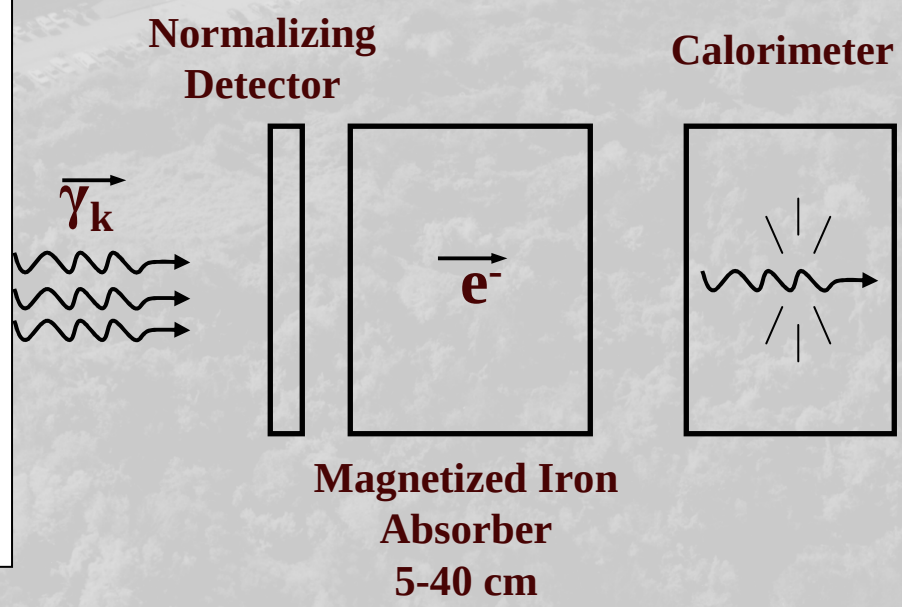
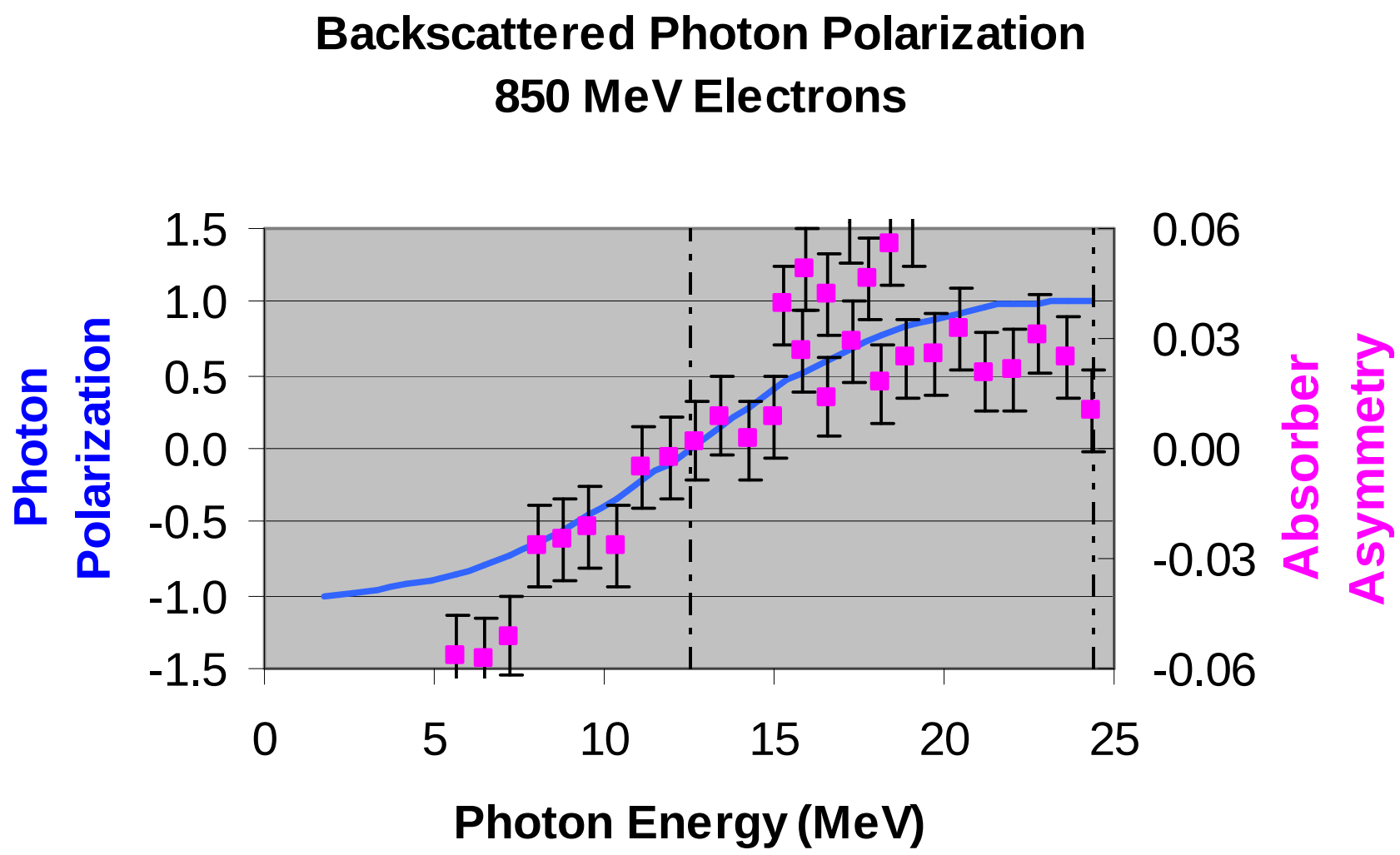
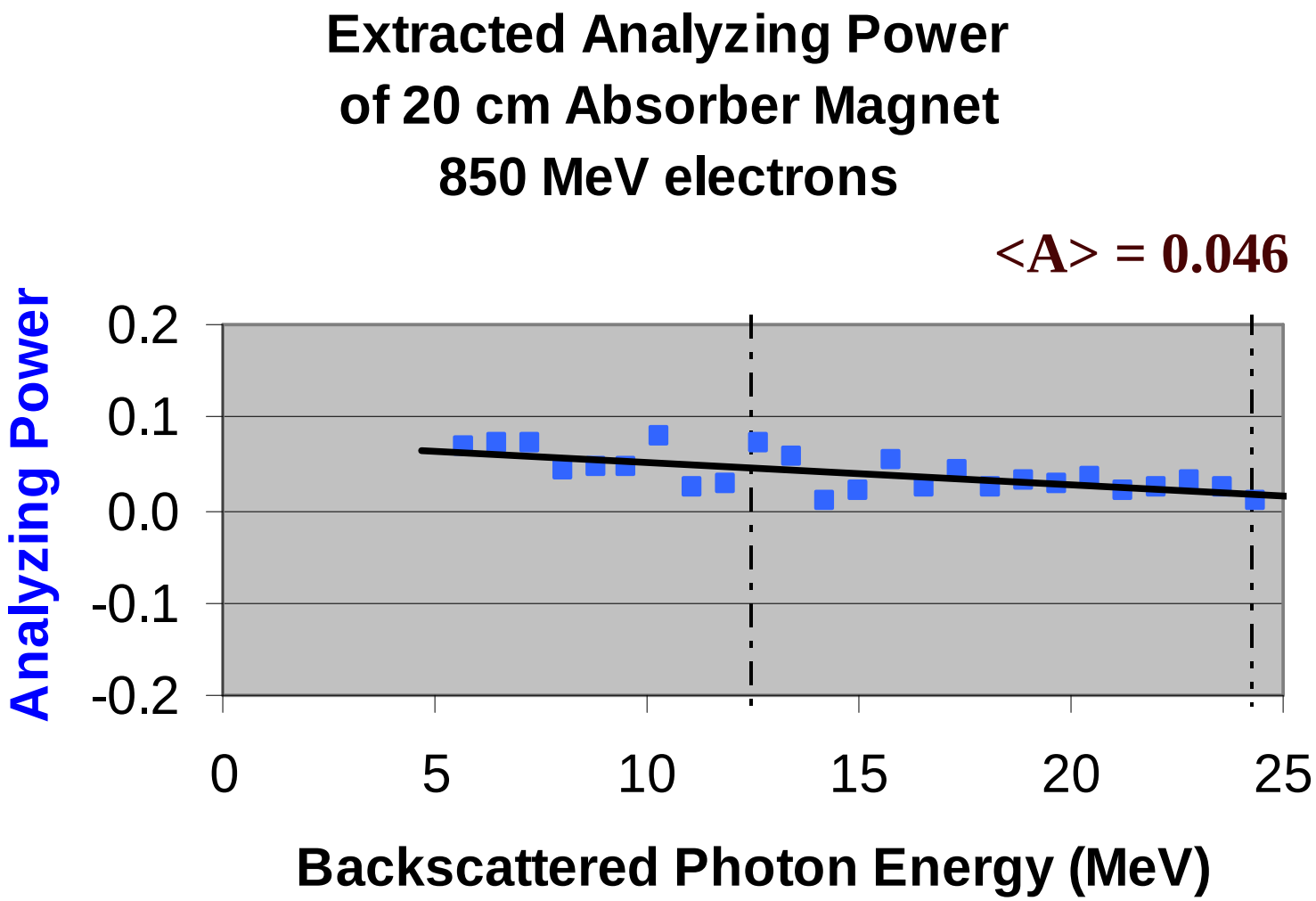
   or

6. Calibrate Analyzing Power Absolutely using Compton Backscatter as Source of 100% Polarized Photons

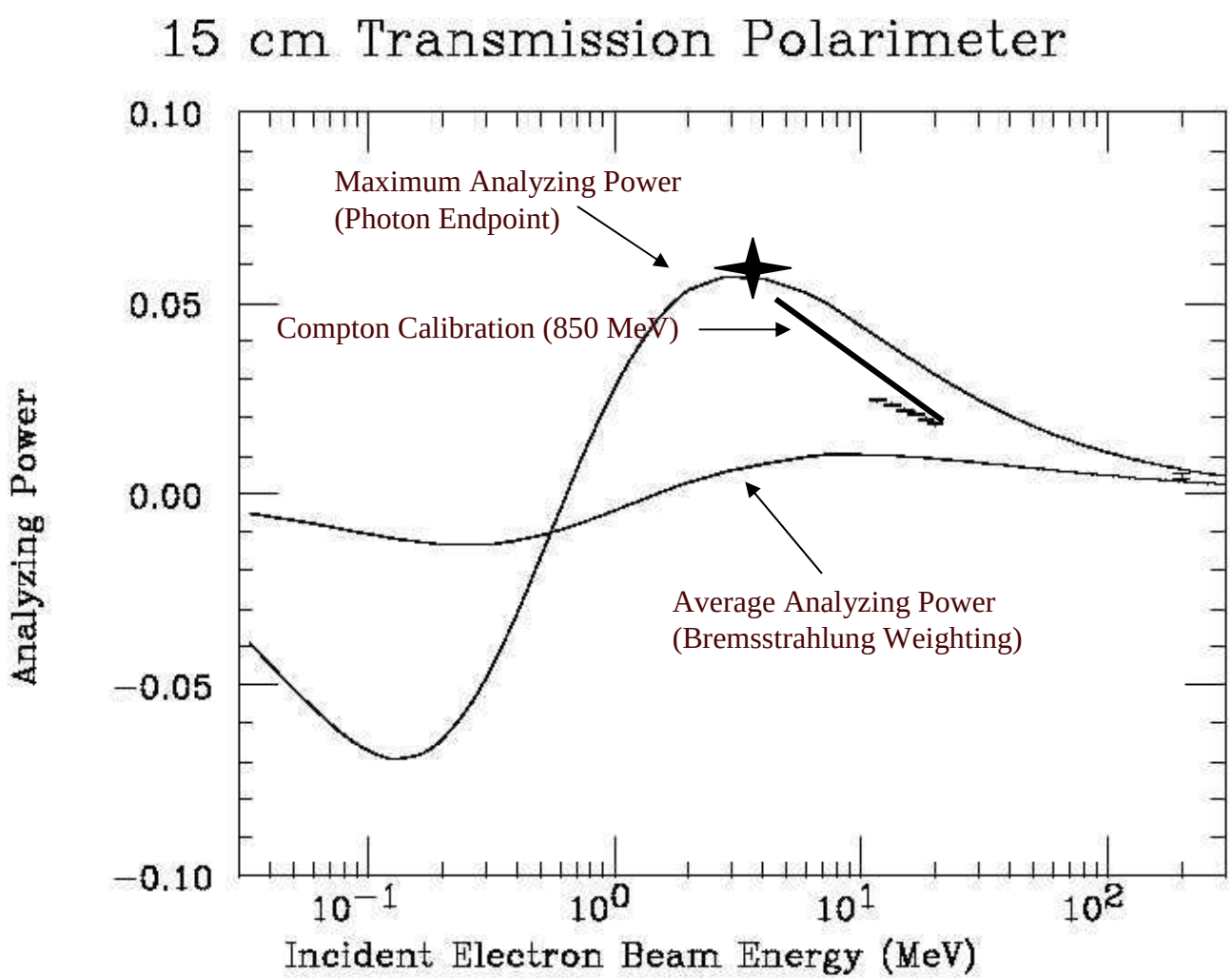





Backscattered Photon Polarization
850 MeV Electrons
Photon Polarization
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0.06
0.03
0.00
-0.03
-0.06
Absorber Asymmetry
0
5
10
15
20
25
Photon Energy (MeV)


Extracted Analyzing Power
of 20 cm Absorber Magnet
850 MeV electrons
<A> = 0.046
Analyzing Power
0.2
0.1
0.0
-0.1
-0.2
0
5
10
15
20
25
Backscattered Photon Energy (MeV)

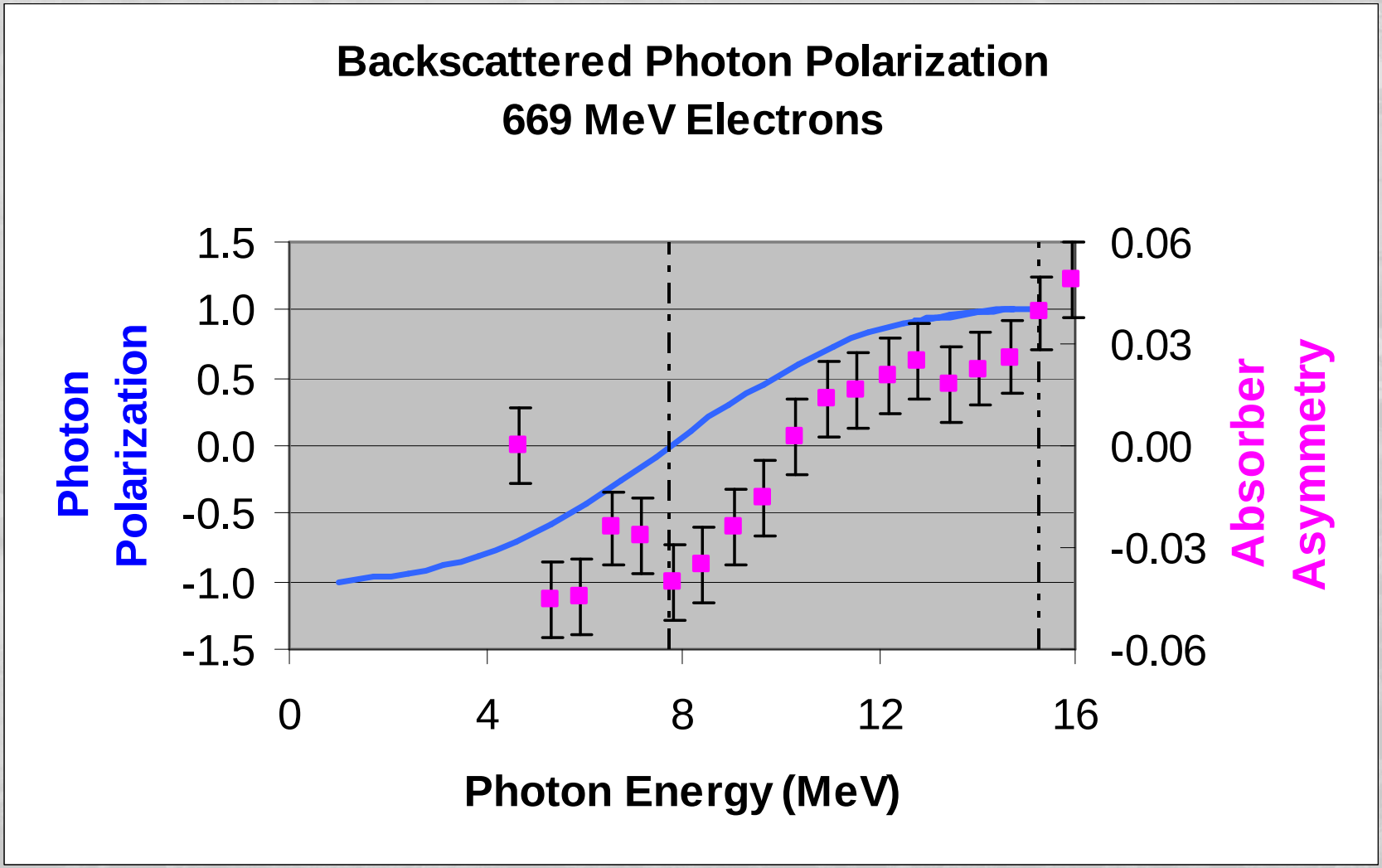
Trans. Polarimeter Analayzing Power

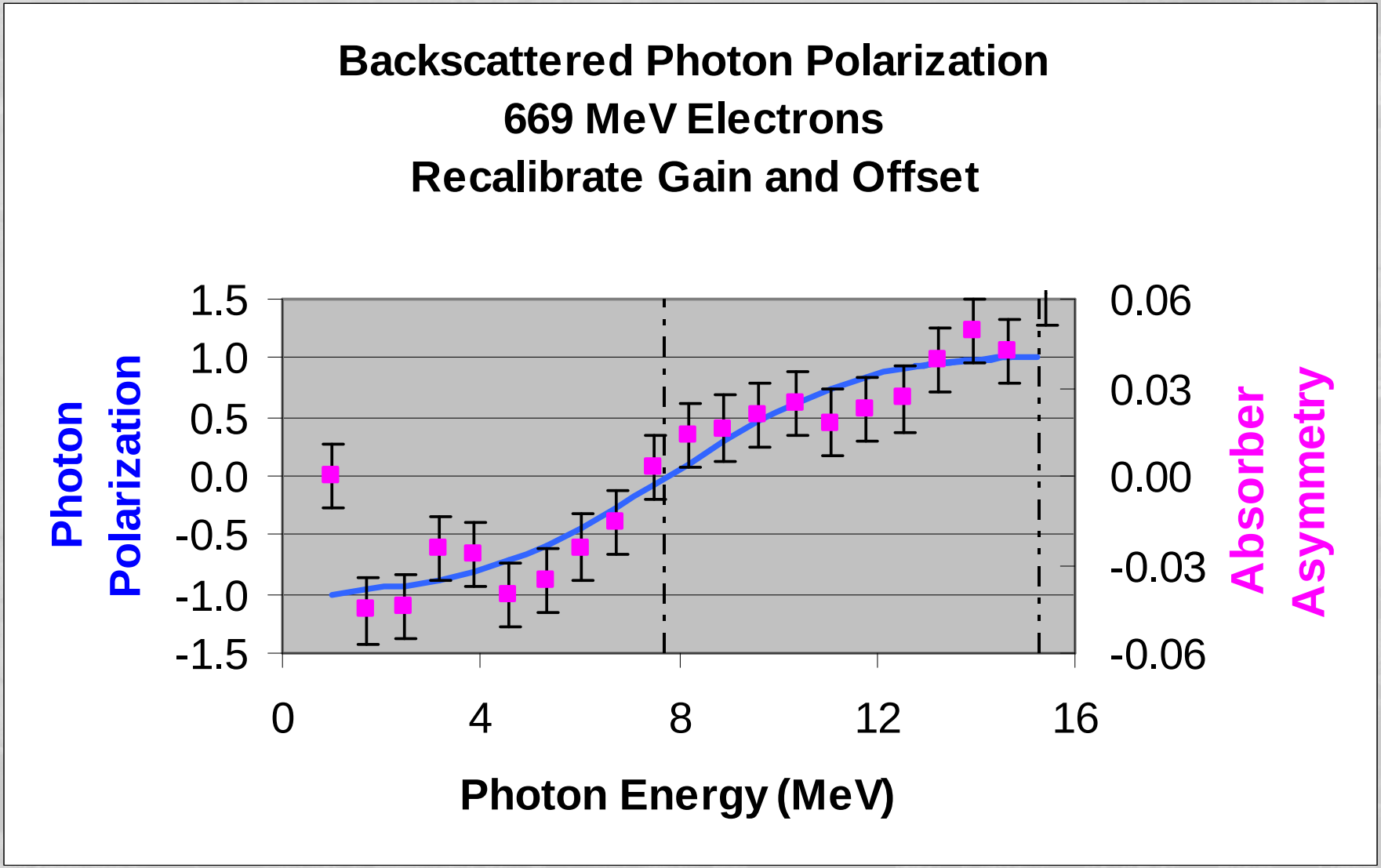


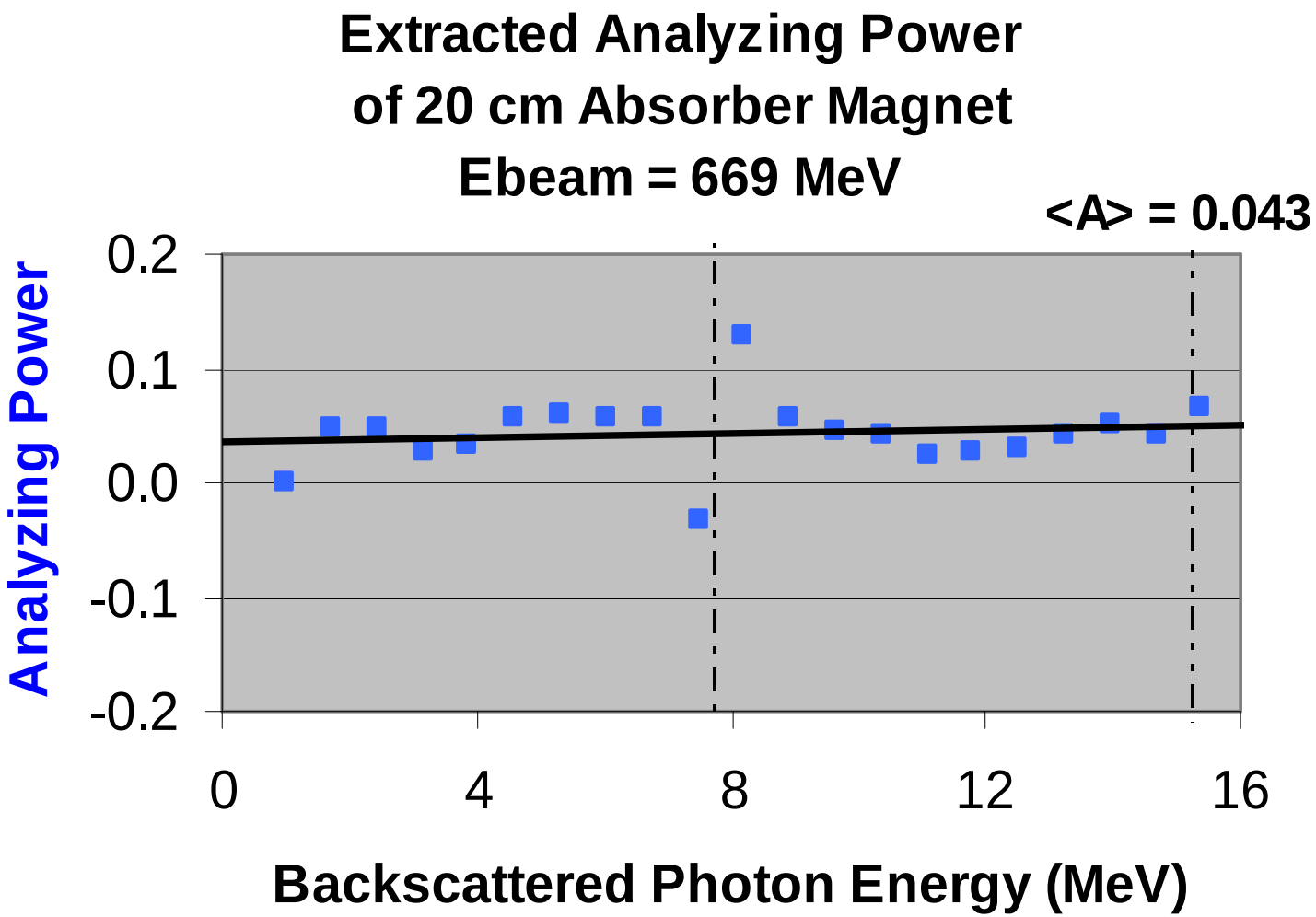
Analyzing Power Calibration

- Backscatter Photon Polarization is given by Laser Polarization
- Laser Polarization is very High. $P_{laser} > 99.0\%$
- Doesn't Rely on Knowledge of Iron Electron Polarization

- Calorimeter Response will be important. Bremsstrahlung spectrum vs. Compton Spectrum.
- Emittance of Analyzed Photon Beam may be important


Backscattered Photon Polarization
669 MeV Electrons
Photon Polarization
Absorber Asymmetry
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0.06
0.03
0.00
-0.03
-0.06
0
4
8
12
16
Photon Energy (MeV)


Backscattered Photon Polarization
669 MeV Electrons
Recalibrate Gain and Offset
Photon Polarization
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0.06
0.03
0.00
-0.03
-0.06
Absorber Asymmetry
0
4
8
12
16
Photon Energy (MeV)


Extracted Analyzing Power
of 20 cm Absorber Magnet
Ebeam = 669 MeV
<A> = 0.043
Analyzing Power
0.2
0.1
0.0
-0.1
-0.2
0
4
8
12
16
Backscattered Photon Energy (MeV)