eRHIC
Longitudinal Laser Backscattering Compton Polarimeter

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Goals:

Small Systematic Error
ΔPe < 1%

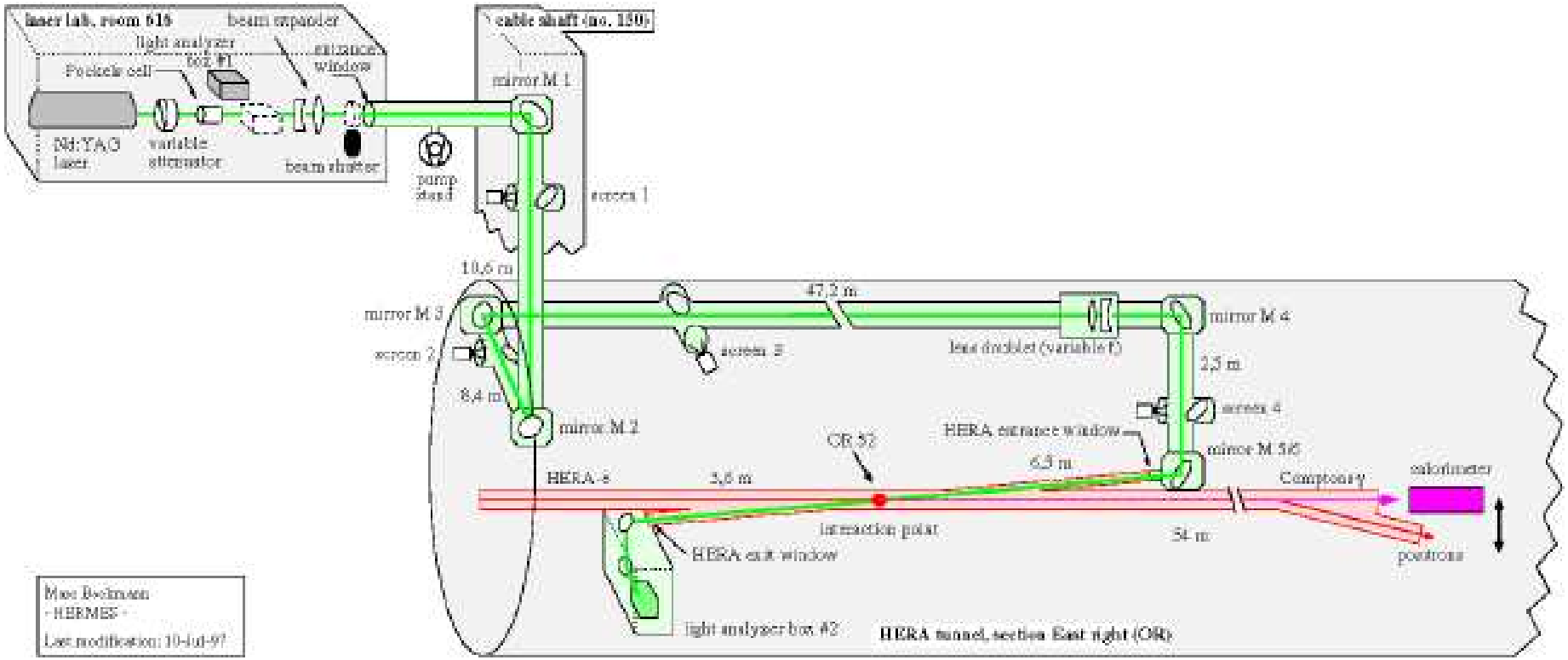
Low Background
S/B ~ 10

High Analyzing Power
A~10%

Fast Polarimeter Response
Statistical ΔPe/Pe<5%/5 minutes
Bunch by Bunch Capability

To achieve this performance the polarimeter must be integrated into the ring design from the beginning

Experimental Setup – Laser System



- M1/2 M3/4 M5/6: phase-compensated mirrors
- laser light polarization measured continuously in box #2

Courtesy W. Lorenzon - University of Michigan

Principle of the P_e Measurement with the Longitudinal Polarimeter

Compton Scattering:

$e+\lambda \rightarrow e'+\gamma$

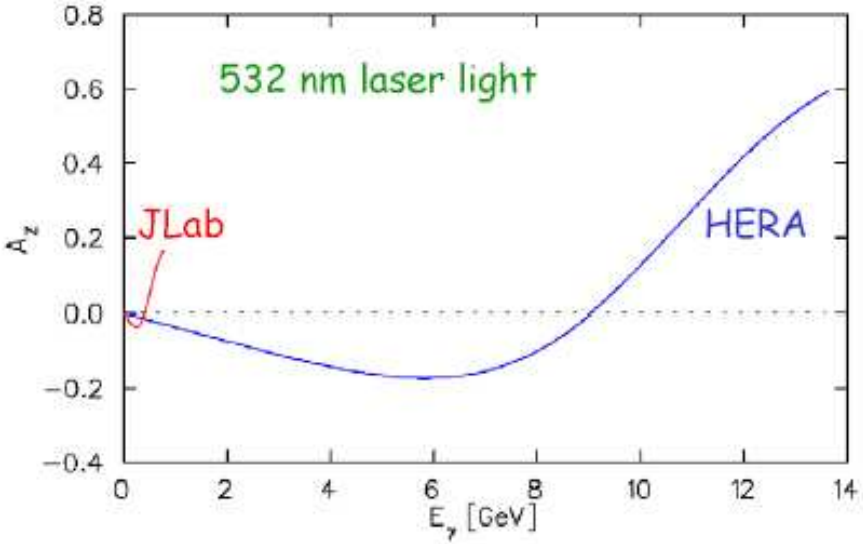
Cross Section:

$d\sigma/dE_\gamma = d\sigma_0/dE_\gamma[1+ P_e P_\lambda A_z(E_\gamma)]$

$d\sigma_0$, A_z: known (QED)

P_e: longitudinal polarization of e beam

P_λ: circular polarization (± 1) of laser beam

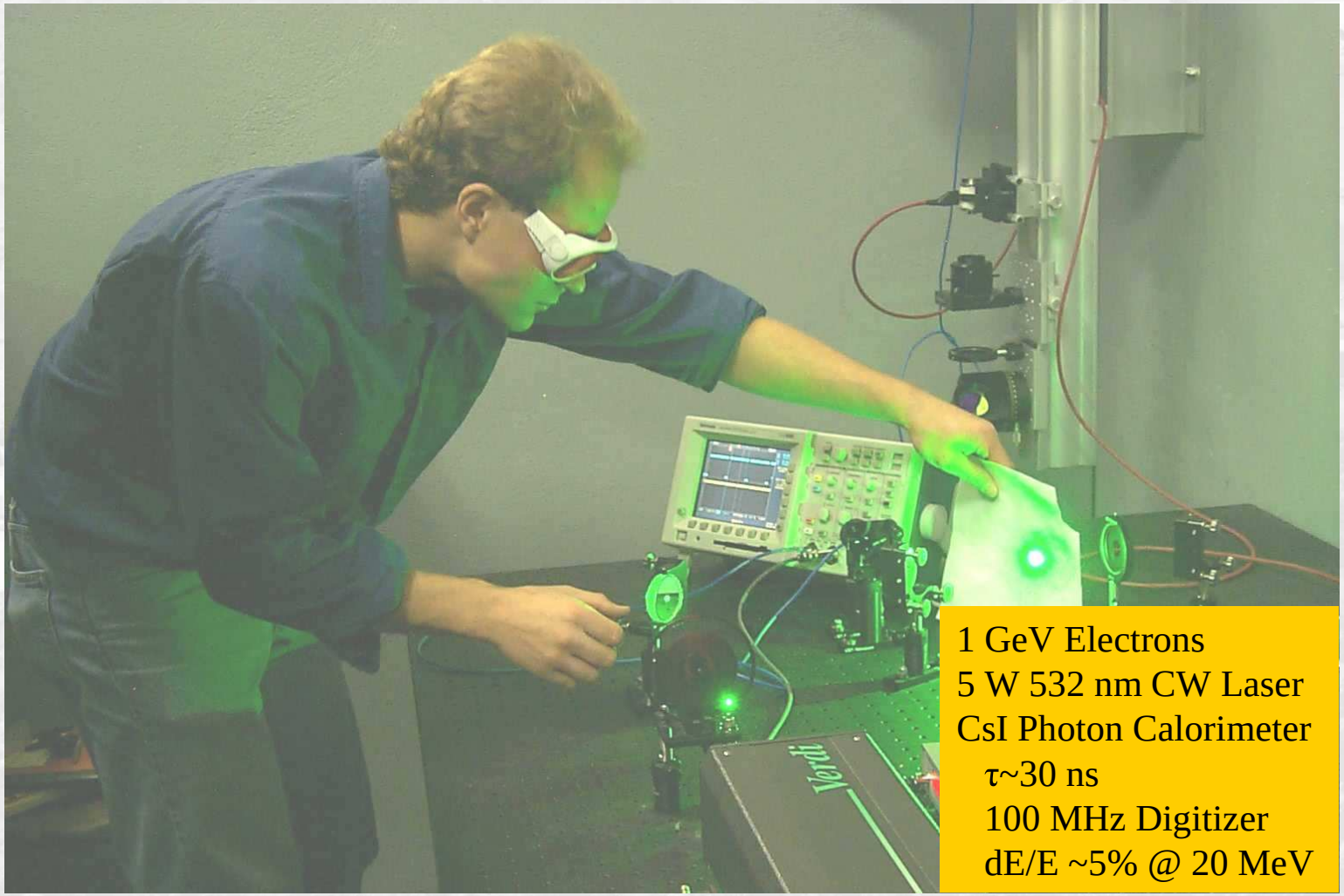


Compton edge: $E_\gamma^{max} \propto E_e^2 E_\lambda$

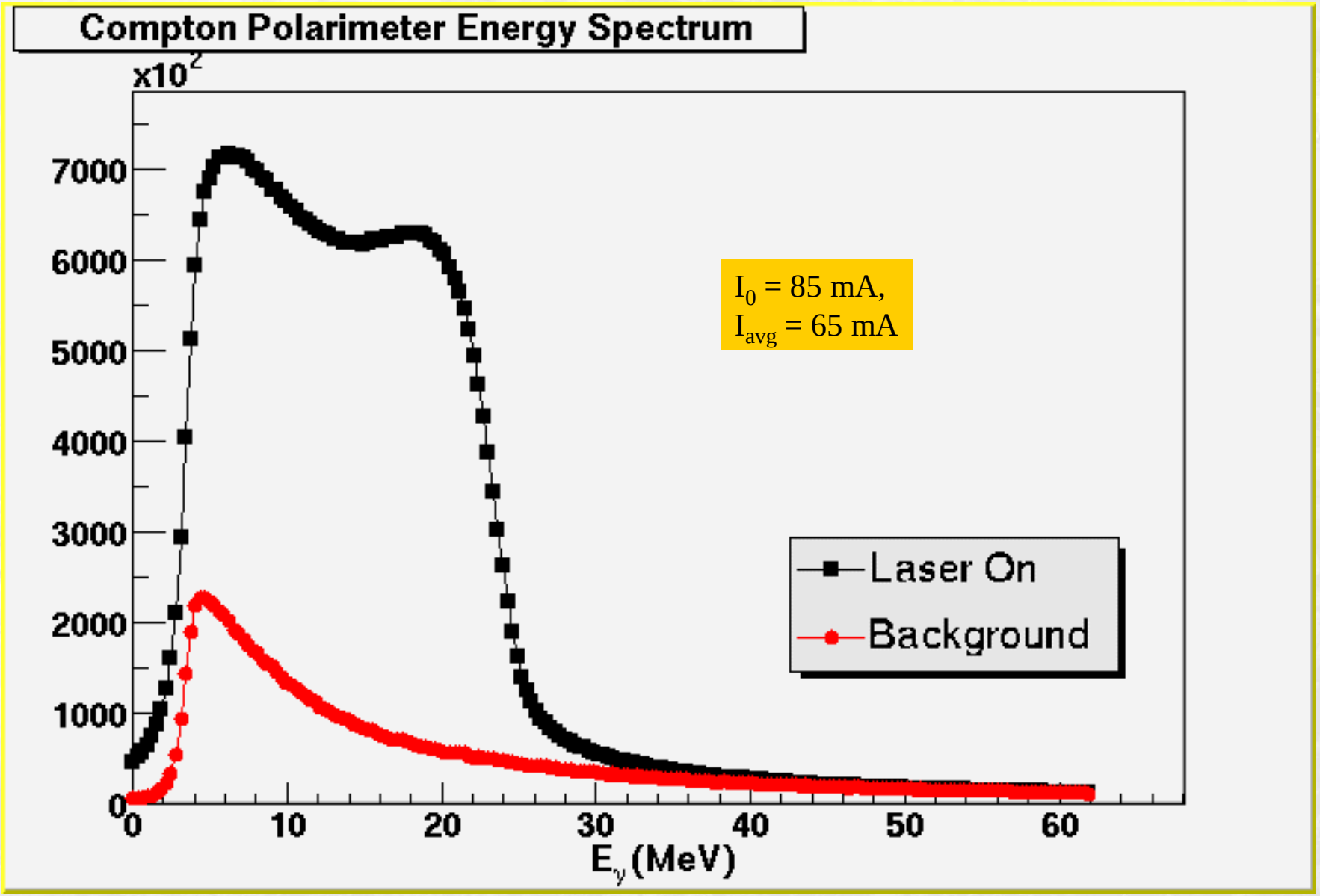
Asymmetry: $A \propto E_e E_\lambda$

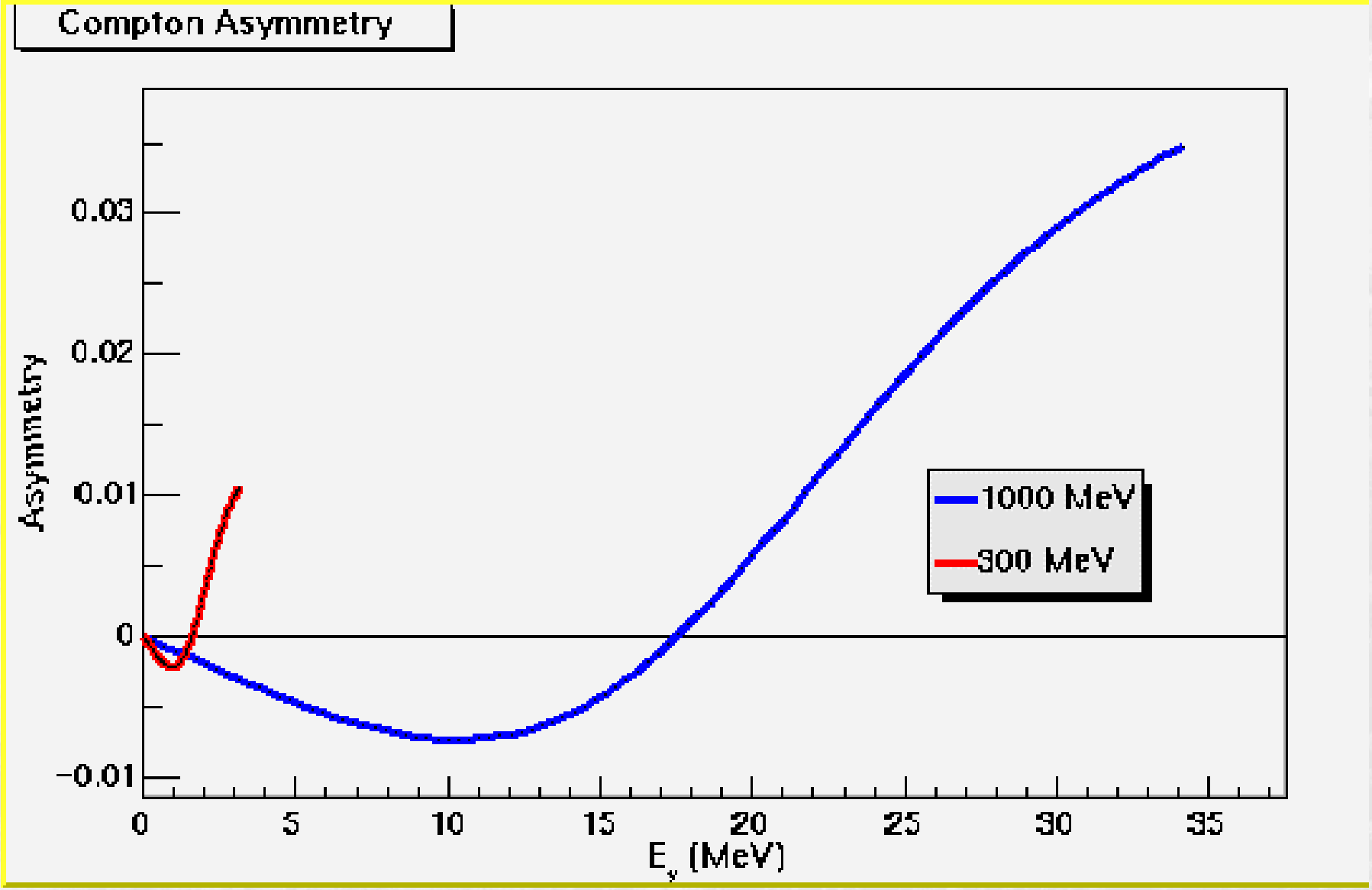
Courtesy W. Lorenzon - University of Michigan

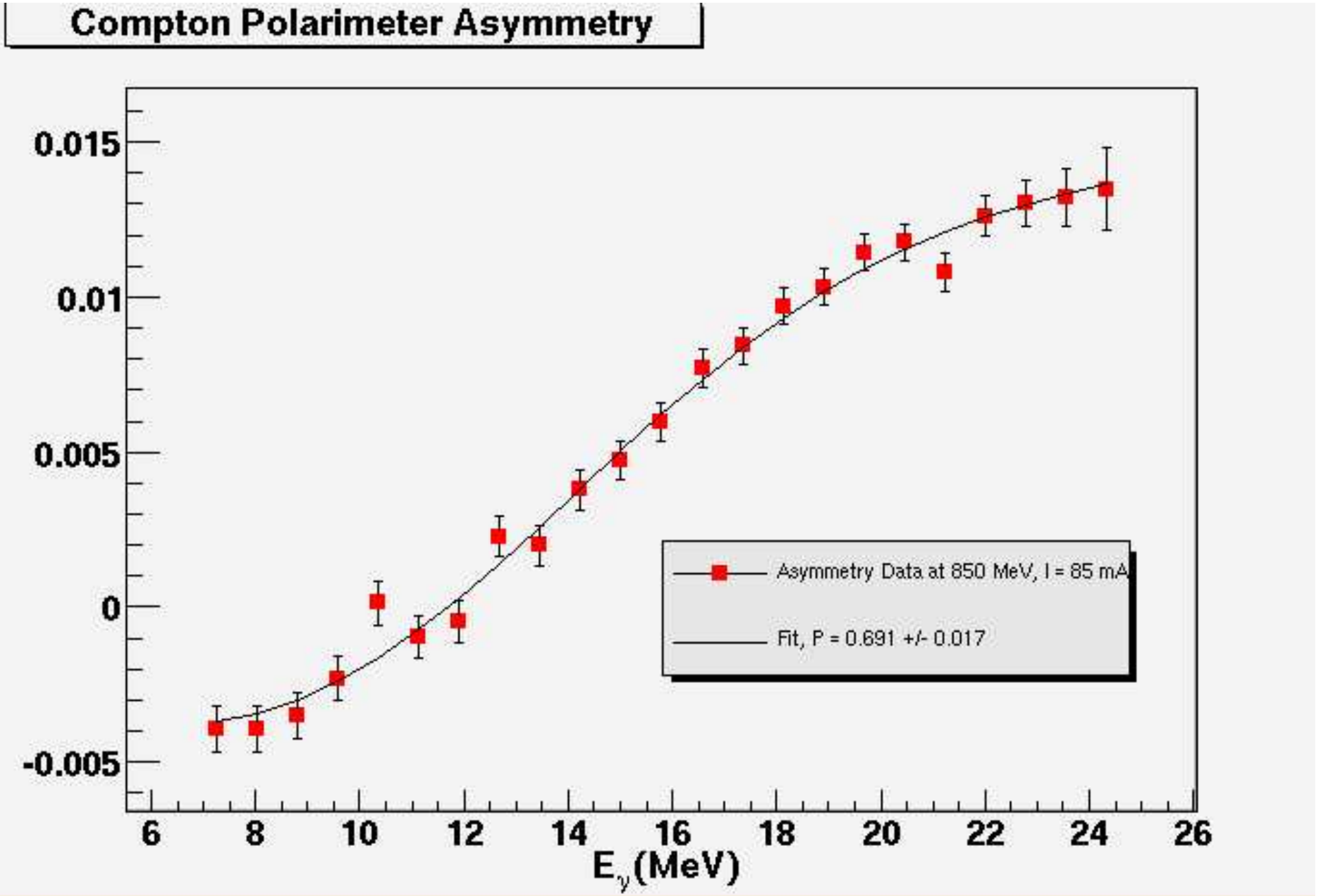
Bates Compton Polarimeter



1 GeV Electrons
5 W 532 nm CW Laser
CsI Photon Calorimeter
τ~30 ns
100 MHz Digitizer
dE/E ~5% @ 20 MeV


Compton Polarimeter Energy Spectrum
x10^2
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
E_γ (MeV)
I_0 = 85 mA,
I_avg = 65 mA
Laser On
Background


Compton Asymmetry
Asymmetry
0.03
0.02
0.01
0
−0.01
0
5
10
15
20
25
30
35
E_γ (MeV)
1000 MeV
300 MeV


Compton Polarimeter Asymmetry
0.015
0.01
0.005
0
-0.005
6
8
10
12
14
16
18
20
22
24
26
E$_\gamma$ (MeV)
Asymmetry Data at 850 MeV, I = 85 mA
Fit, P = 0.691 +/- 0.017

Bates Compton 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 ($\Delta P < 0.01$)

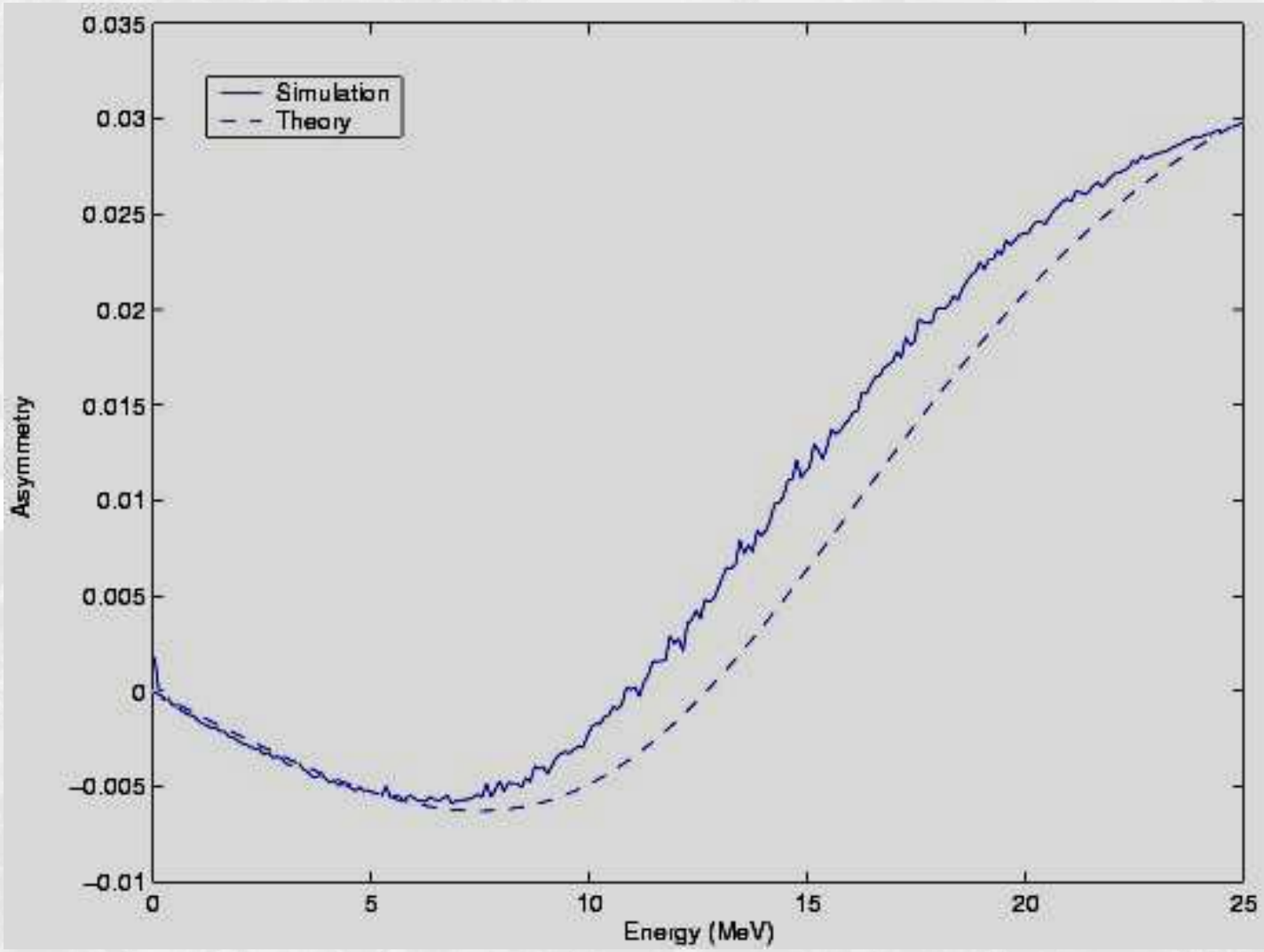
NIKHEF - AmPS

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_n	0.003
Energy spectrum shift	0.001
Luminosity asymmetry	0.001
Total	0.027

Geant Simulation of Calorimeter Response

M. Hurwitz - MIT



Systematic Uncertainties

Source	$\Delta P_e/P_e$ (%) (2000)
Analyzing Power A_p	$\pm 1.2^{\alpha}$
- response function	(± 0.9)
- single to multi photon transition	(± 0.8)
A_p long-term instability	$\pm 0.5^{\beta}$
- PMT linearity (GMS system checked)	(± 0.4)
Gain mismatching	$\pm 0.3^{\gamma}$
Laser light polarization	± 0.2
Pockels cell misalignment	$\pm 0.4^{\gamma}$
- $\lambda/2$ plate (helicity dep. beam shifts)	$(\pm 0.3)^{\gamma}$
- laser-electron beam overlap	$(\pm 0.3)^{\gamma}$
Electron beam instability	$\pm 0.8^{\gamma}$
- electron beam position changes	$(\pm 0.6)^{\gamma}$
- electron beam slope changes	$(\pm 0.5)^{\gamma}$
Total	$\pm$ **1.6**$^{\delta}$

$^{\alpha}$ new sampling calorimeter built and tested at DESY and CERN

$^{\beta}$ from comparison with prototype sampling calorimeter

$^{\gamma}$ statistics limited

$^{\delta}$ published in NIM A 479, 334 (2002)

Courtesy W. Lorenzon - University of Michigan

SLAC -SLD

M. Woods - SLAC

46 GeV Electrons

532 nm Laser

Systematic Error $\Delta Pe = 0.5\%$

SLAC measures scattered electron & photon

Pulsed Laser Required

As reported in the JLAB 2003 precision polarimetry workshop, SLAC has the lowest systematic error

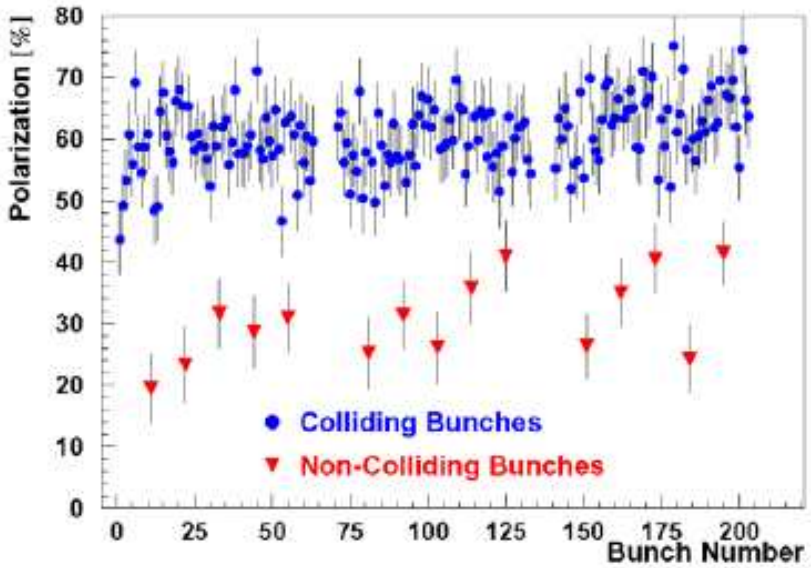
Polarization Performance

HERA: 220 bunches separated by 96 ns

174 colliding + 15 non-colliding = 189 filled bunches

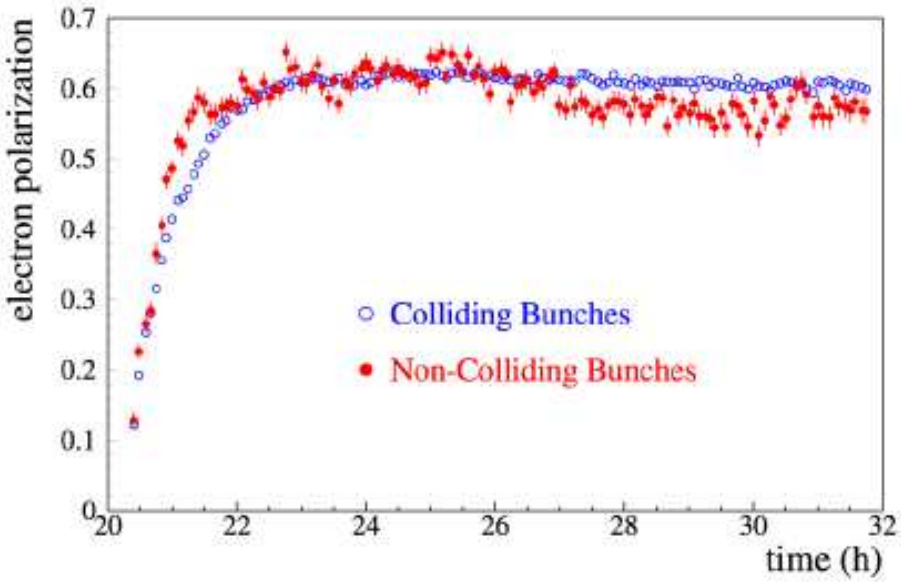
20 min measurement

dP/P = 0.03 in each bunch



time dependence:

helpful tool for tuning



Courtesy W. Lorenzon - University of Michigan

eRHIC LPOL Laser

Pulsed vs CW Laser:

Pulsed Laser supresses Brem. background

CW laser can have better pointing and position stability

Laser Wavelength:
532 nm may be adequate. Substantially easier than working in the UV.

UV moves compton backscatter away from Brem tail

Polarization Preparation
Stored beam time structure is compatible w/ use of waveplates rather than Pockels cells to prepare circular polarization. Far superior Pcirc as compared to Pockels cells.

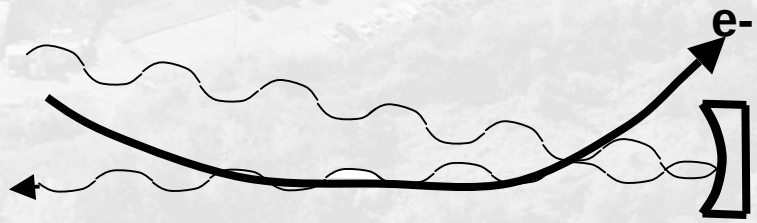
eRHIC LPOL Interaction Region

Introduce laser from upstream (E. Ihloff)

Preserves near normal Incidence on mirror

Polarization transport greatly simplified and
"False" Luminosity Asymmetries Surpressed

Similar to solution for Bates polarized injector as
required by the SAMPLE parity experiment
(Kowalski, Beck)



No Magnetic elements (quadrupoles) in IR

XHV vacuum system in IR. Bakeable. Ion clearers.
NEG material on Beampipe ID

Chicane would require ~30 m and bad for spin

eRHIC LPOL Detectors

eRHIC polarimeter should include e' detectors

- **Required Energy resolution is Modest dE/E~3%**
- **Electron detectors can be sufficiently segmented to avoid pileup**

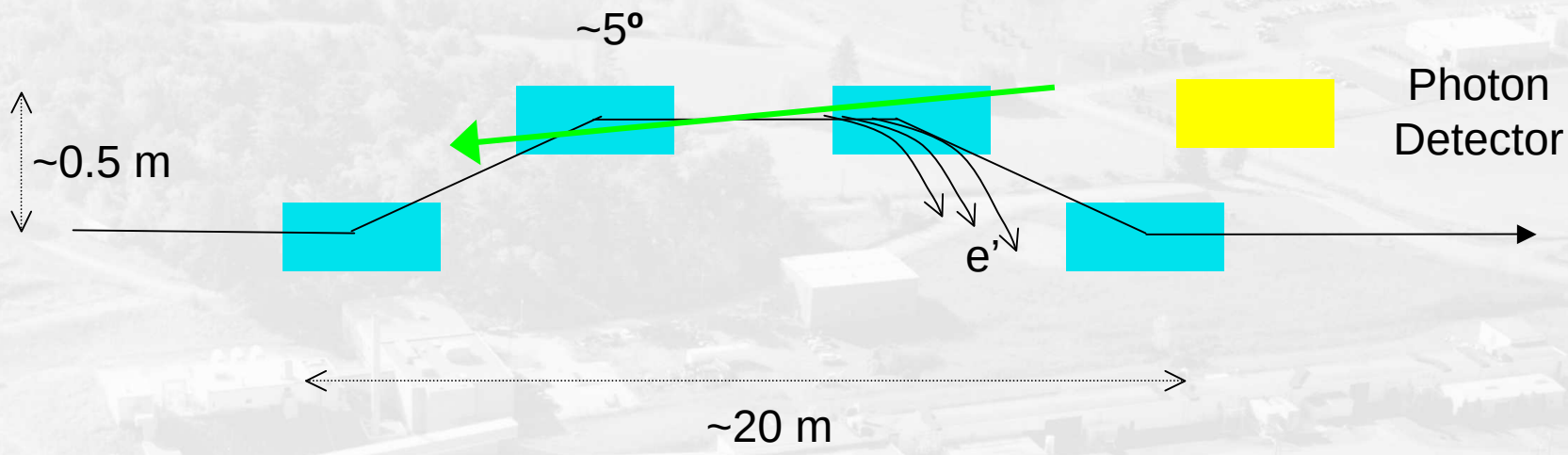
Tagger detector should only image short (~3m) section of straight section. → Dipole Must preceed e-laser IR

Photon detector should be added for redundant measurement

Electron Tagger will require sufficient dispersion downstream of the e-laser IR to detect
e' = ~0.8 e_0 at ~10 cm from e_0 → ~3º Dipole x 20 m
cf D. Wang 35,34 mr.

Possible integration of Tagger in last dipole of spin rotater? g-2 correction of 45 º. Septum and spectrometer magnets required?

Chicane for Compton Polarimeter

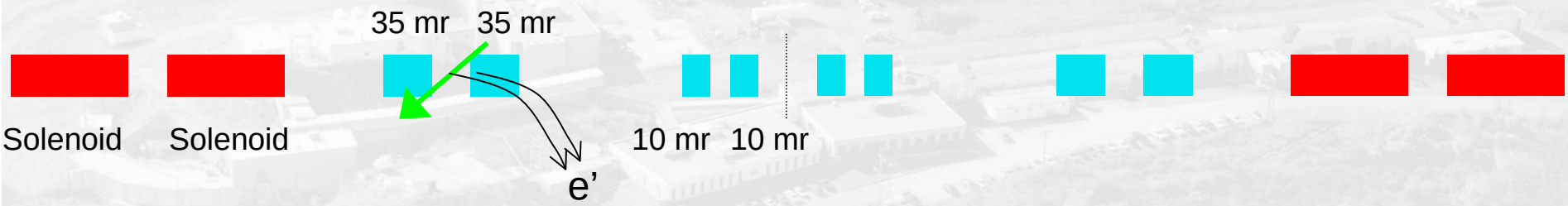


Preserves Long. Polarization @ Compton
Short Section For Brem. Background
Sufficient Bending for separation of e'

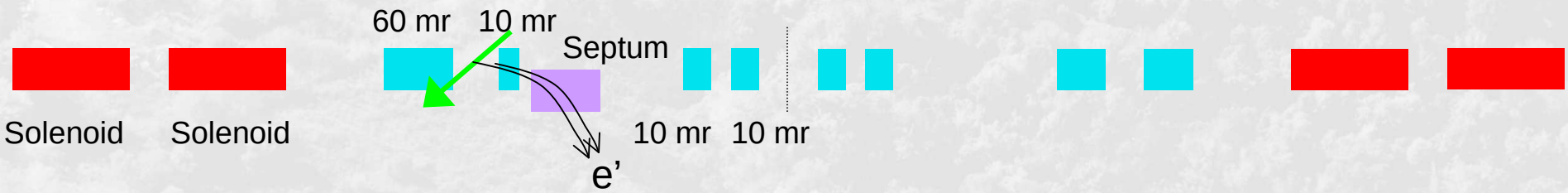
Probably unworkable
•Spin Transparency
•20 mr of Dipoles in IR anway (B. Parker)

Use Last Rotator Dipole Outside IR for Tagger

90º of Spin Precession @ 7.5 GeV → 5.3 º Bend



35 mr precesses spin 22º @ 5 GeV, 45 º @ 10 GeV
Not Really a Longitudinal Polarimeter



35 mr precesses spin 37º @ 5 GeV, 74º @ 10 GeV
Septum Required

Conclusions

Polarimeter not yet included in ZDR IR design

Machine group should offer proposed Compton configuration to Lorenzon, Franklin et. al.

Lorenzon, Franklin, et. al. should offer proposed Compton configuration to machine group.