A4 Laser Compton polarimetry

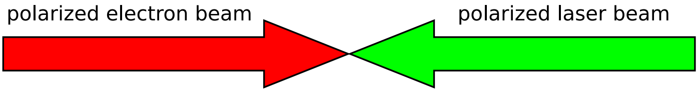
progress since PAVI06

J. Diefenbach

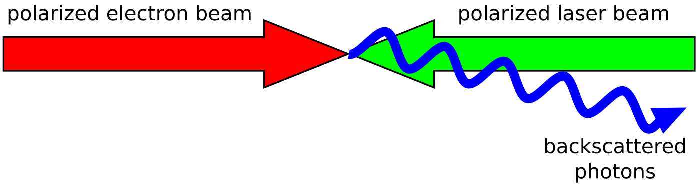
Workshop on Parity Violation 2009, Bar Harbor, Maine - 24.06.2009

Outline

Colliding beams



Colliding beams



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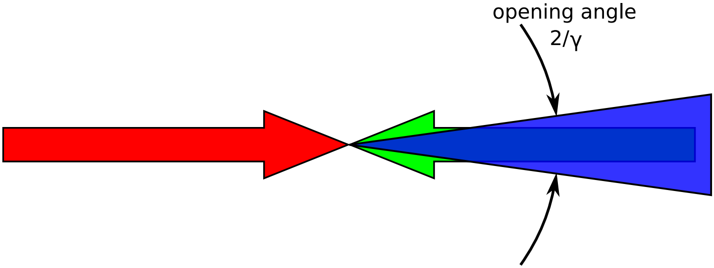
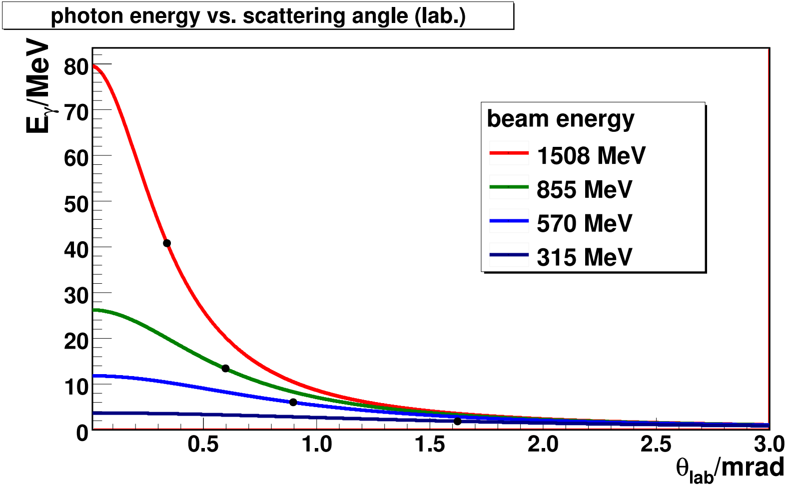


Scattering Angle (lab frame)

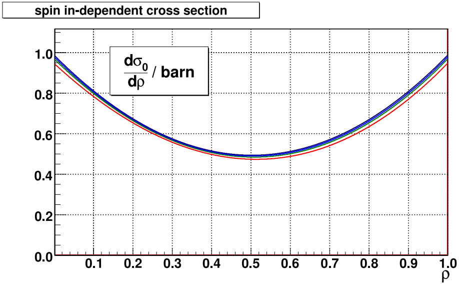


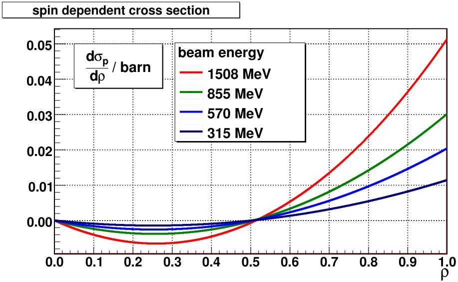
514.5 nm Argon-Ion laser light

Cross section

$$\sigma = \sigma_0 \mp P_e P_\gamma \sigma_p$$

$$\rho = k/k_{max}$$





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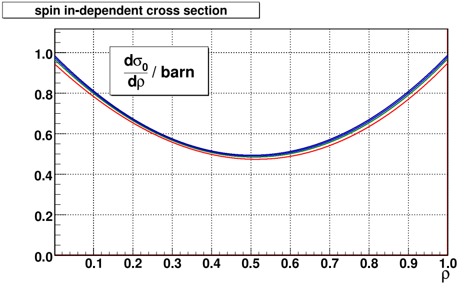
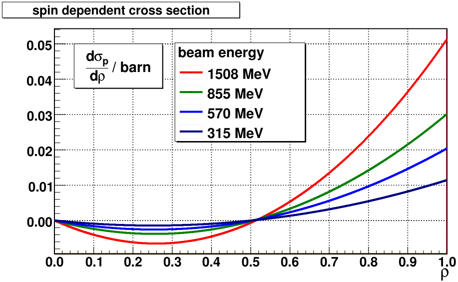
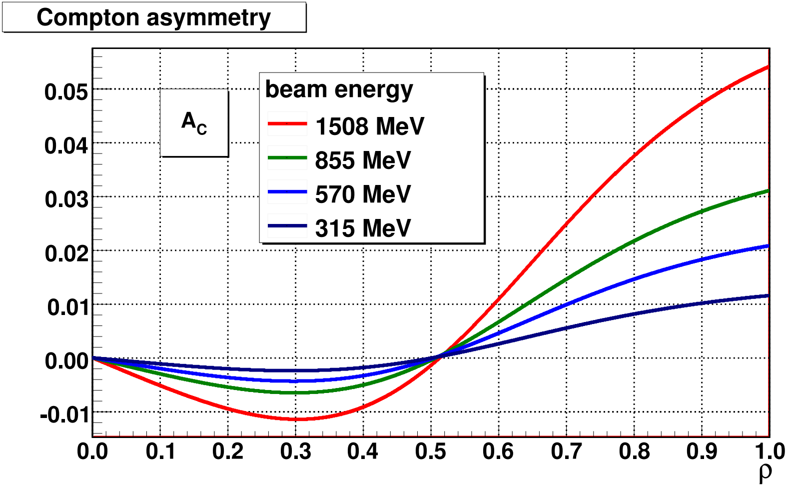




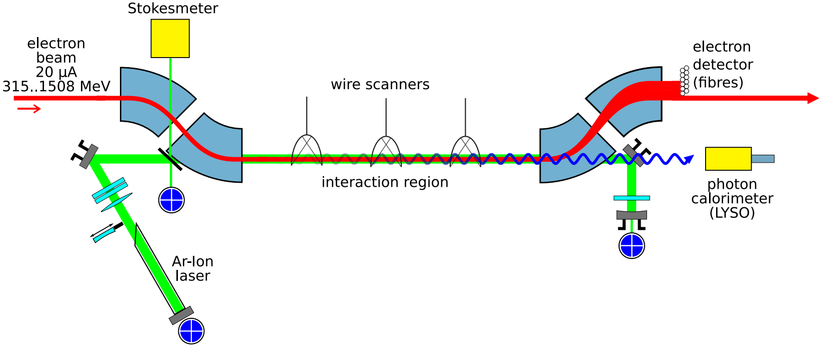
514.5 nm Argon-Ion laser light

Compton Asymmetry



514.5 nm Argon-Ion laser light

Overview of the A4 Laser Compton polarimeter

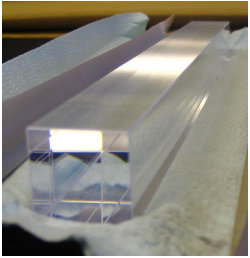


- Making use of high laser power inside cavity
- Zero crossing angle
- Fast, semi-automatic overlap procedure (typ. 15..60 min)
- Fast, high-resolution detectors

Photon detector I

LYSO (*$Lu_{1.8}Y_{0.2}SiO_5$*),
PreLude420 from Saint Gobain

- density: 7.1 g/cm^3
- rad. length: 12 mm
- decay time: 41 ns
- light yield: 32 photons/keV, i.e. $\approx$75% of NaI(Tl)



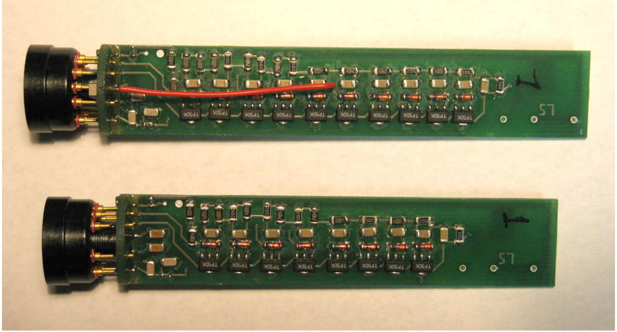
crystals of 20x20x200 mm^3

3x3 crystals, wrapped in DF2000MA (3M reflective foil)

Fast, compact calorimeter for 1.5 ... 100 MeV photons

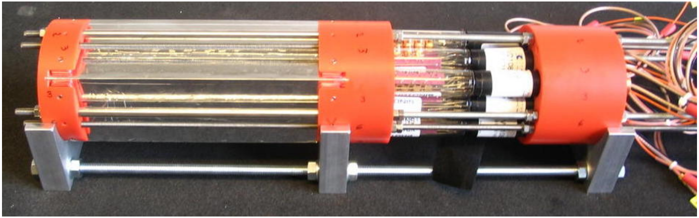
Photon detector II

Active bases for PMTs for high rates (200 kHz or more)

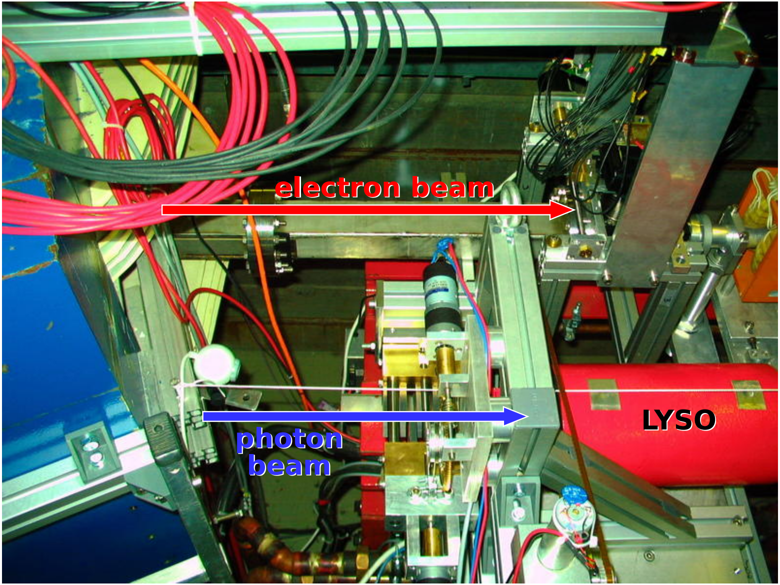


Two types of PMTs:
XP1981 (low gain) for 855 and 1508 MeV (up to 80 MeV)
XP1921 (high gain) for 315 MeV (3.6 MeV max.)
Can be exchanged within 60 minutes

Photon calorimeter III



Photon calorimeter III



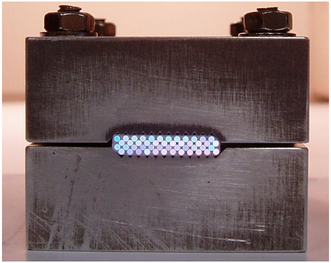
Electron fibre detector

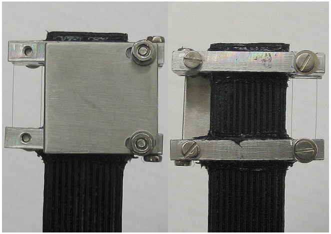
48 scintillating fibres
Kuraray SCSF-78M
0.83 mm diameter
0.73 mm active core

2x2 stacked layers
24 channels

1 mm steel against synchrotron radiation

tungsten wires for position calibration

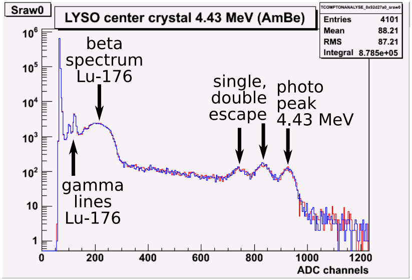


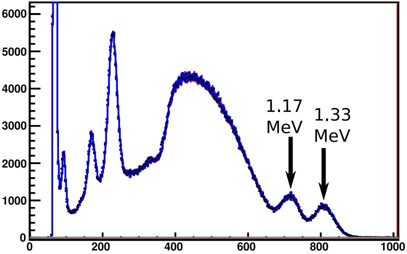


Detector has been operated at 3 mm distance from beam!

Energy calibration I

At low energies calibration of each crystal on ^{60}Co or AmBe neutron source (4.43 MeV)

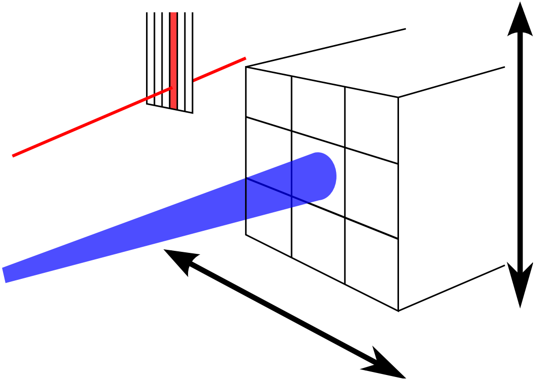




Works very well up to 855 MeV (26 MeV max. photon energy)

Energy calibration II

For 1508 MeV beam energy (up to 78 MeV photons) use tagged photons:



$$E_{beam} + k_0 = E_e + k$$

Energy calibration II

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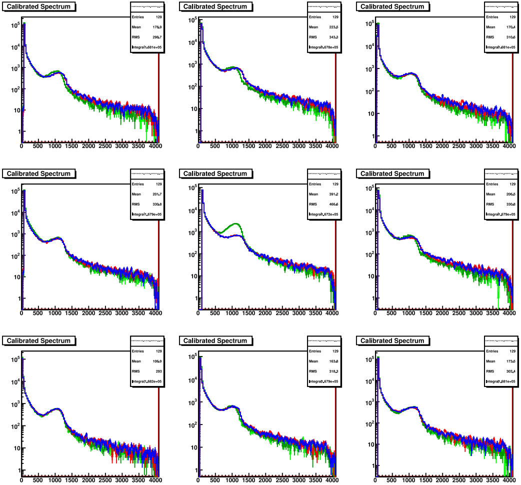
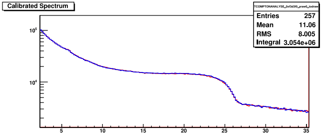
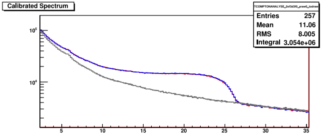


Data taking



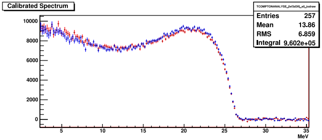
- Runs with laser light

Data taking



- Runs with laser light
- Runs without laser light (background subtraction)

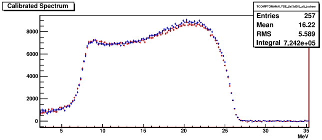
Data taking



- Runs with laser light
- Runs without laser light (background subtraction)

- Trigger on every photon:
- “unbiased” spectra

Data taking



- Runs with laser light
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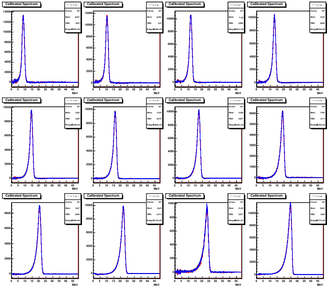
- Trigger on every photon:
- "unbiased" spectra
- also read out fibre detector
  - software trigger:
    - "concidence" spectra ($\gamma + e$)

Data taking



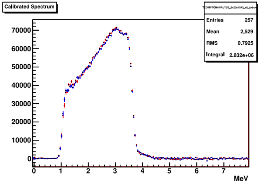
- Runs with laser light
- Runs without laser light (background subtraction)

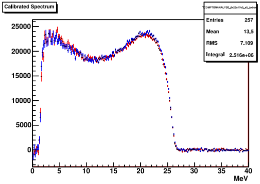
- Trigger on every photon:
- “unbiased” spectra
- also read out fibre detector
  - software trigger:
    - “concidence” spectra ($\gamma + e$)
    - “tagged photon” spectra (one per fibre)

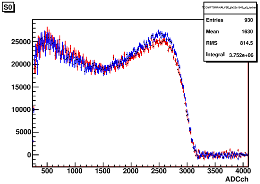
Typical spectra

315 MeV | 855 MeV | 1508 MeV

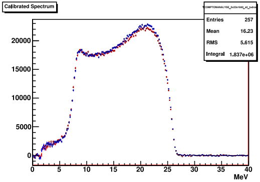
unbiased

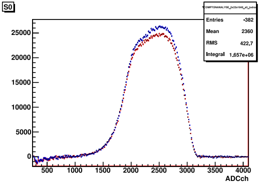






concidence





Compton asymmetries

The simple way:

Calculate asymmetry from red and blue spectra

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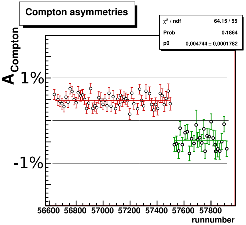
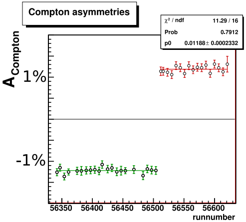
Calculate asymmetry from red and blue spectra

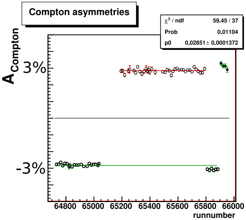
315 MeV



855 MeV



1508 MeV



$\approx$1 % in 24 h

<1 % in 12 h

Analyzing power

The simple way:

Calculate asymmetry from red and blue spectra

Problem:

Accuracy of detector response simulation??

Analyzing power

The simple way:

Calculate asymmetry from red and blue spectra

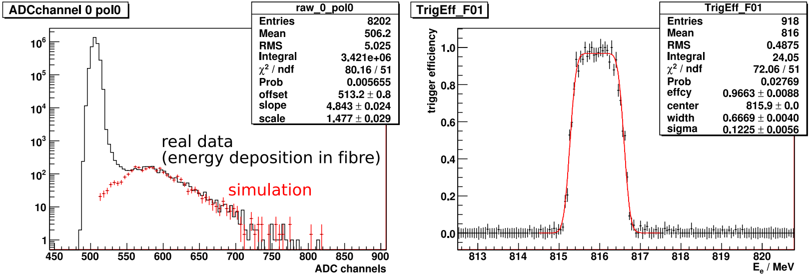
Problem:

Accuracy of detector response simulation??

Solution:
- Use fibres as photon tagger!
- Parametrize fibre trigger efficiencies
- Simultaneous fit of detector response simulation to tagged photon spectra

Suppression of systematics

Simulate and parametrize fibre trigger efficiencies:



Analyzing power for corresponding tagged photons can now be calculated

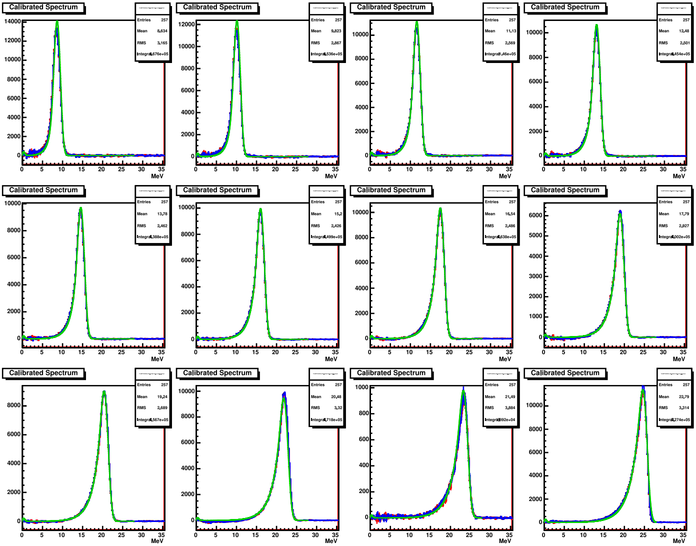
Suppression of systematics

Perform simultaneous fit of detector simulation
to tagged photon spectra with

- Chicane dispersion
- Effective fibre bundle position
- Beam position fluctuations etc.

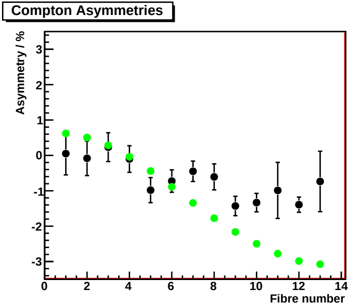
Perfectly describes tagged photon spectra! (non-trivial!!)

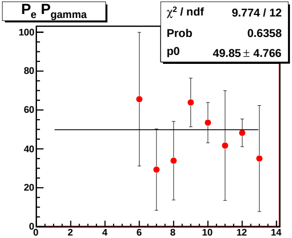
Suppression of systematics



Suppression of systematics

855 MeV data:





black: measured
green: expected asymmetries

ratio black/green = $P_e P_{gamma}$

Conclusion and Outlook

- routine operation during parity beamtimes
- Compton asymmetry data at 315, 855, 1508 MeV:
  - $\approx$1 $\%_{stat}$ in 24 hours at 855 MeV
  - <1 $\%_{stat}$ in 12 hours at 1508 MeV
- low systematics when using tagged photon spectra: <1 $\%_{syst}$ (+ <1 $\%_{syst}$ from Stokesmeter) expected

- Independent, absolute, non-destructive polarization measurement for the 1.5 GeV PVA4 beamtimes!