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THE COMMISSIONING OF THE LEP POLARIMETER

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Abstract A laser polarimeter has been installed in LEP to measure the transverse beam polarization. We describe the layout, the production and the control of the polarization of the laser light, the photon detector and the data acquisition philosophy. The commissioning experience in the first year of operation of the device is discussed together with recent results on the detection of transverse polarization.

1 Introduction

Studies on transverse polarization in LEP with simulation programs anticipated limitations from several effects like betatron coupling and residual vertical dispersion. A rather poor polarization level was then expected to be available by the end of the first year of LEP operation and a fast polarimeter [1] [2] capable of monitoring polarization changes of a few percent has been designed and installed as an essential tool to optimize orbit correction strategies required to improve the polarization level.

2 The Compton polarimeter

Suggested by Baier and Khoze [3] the laser polarimeter is based on spin-dependent Compton scattering of circularly polarized photons from polarized electrons or positrons.

In presence of transverse beam polarization the vertical angular distribution of the recoil high energy γ-rays shows an *up-down asymmetry* proportional to the lepton and photon polarization level, which flips sign under reversal of the handedness ξ_3 of the incident photons [4]:

$$A_T(y) = \frac{n_R - n_L}{n_R + n_L} = P_\perp\ \xi_3\ \Pi_T(\theta', k'_o)\ sin\,\phi', \qquad (1)$$

where $n_{R,L}(y)$ are the γ-rates at a vertical position y at the detector, Π_T is the transverse analyzing power while the kinematic notations are defined in [5].

The asymmetry (1) can be expressed in terms of the *mean shift* $\Delta\langle Y\rangle$ between the center-of-gravity of the two γ-distributions produced by the helicity states $\xi_3 = \pm 1$:

$$\Delta\langle Y\rangle = \kappa\ \xi_3\ P_\perp\ , \qquad (2)$$

where the *mean-shift for full electron and photon polarization* κ simulated for our polarimeter is : $\kappa = 500 \pm 30\,\mu$m.

3 Layout

Quantitative considerations on background from gas bremsstrahlung and synchrotron radiation have been accounted for in [1] and guided the choice of the layout.

The 90 mJ light pulses from a 30 Hz Nd-YAG laser operated in the visible range (λ_ϕ = 532 nm) and installed in an Optical Laboratory $\sim$ 15 m off the LEP tunnel are guided towards the Laser Interaction Region (LIR) over $\sim$ 115 m in a roughly evacuated beam pipe including three lenses and five multilayer dielectric mirrors. The final deflection onto the e^- beam under an angle of $2 \div 3$ mrad is provided by ($Ag + Mg\,F_2$)-coated Cu mirrors [6]. Their position in the LIR vacuum chamber can be remotely adjusted to operate the polarimeter in parasitic mode during physics runs without affecting the beam life time nor the mirror reflectivity. Hundreds of high energy γ's per laser shot are backscattered in a 5-28 GeV range and reach the detector 247 m downstream the LIR through a $50 \times 20\,mm^2$, 2 mm thick Al-window built in the modified vacuum chamber in the B1 main dipole about 225 m from the interaction point.

The upstream 10% weak dipole prevents the detector from being reached by the 56 keV critical energy synchrotron radiation from the LEP main dipoles. Proper shielding against the radiation emitted in the quadrupoles and the orbit correctors along the LSS1 straight section [1] has nevertheless to be provided.

Six TV cameras have been recently installed on the laser line for the alignment of the light beam on mirrors, windows and diaphragms.

4 The detector

Silicon calorimeters have been developed and successfully employed in 1990 [7] for the LEP luminosity monitors. Silicon strip planes behind a remotely-controlled variable-thickness lead absorber also constitute the active part of the polarimeter detector to measure the profiles of the recoil photons.

Some modifications to the calorimeter used in the 1990 runs have been performed during the '90/'91 shutdown and the new layout is shown in Fig. 1. Four strip detectors ($S_1 - S_4$) and five unsegmented pads ($F_1 - F_5$) are inserted between tungsten plates. The 40 mm × 40 mm

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"S" detectors have 16 horizontal strips with 2 mm pitch. The $S_{1,2,3}$ strip planes measure the vertical γ-profile and the S_4 the horizontal one. The first S_1 detector just behind 0.5 radiation lengths is intended to monitor the profile of the synchrotron radiation since any change of the mean value indicates a change of the beam position. The other detectors are installed after a 2 r.l. of tungsten.

The resolution of the polarimeter is proportional to the number of photons from Compton scattering which can vary in a wide range according to the luminosity of the laser-beam interaction. To cover this range strip detectors S_2 and S_3 are equipped with preamplifiers of different gain and they can be chosen according to the photon flux.

The five full plane "F" detectors are meant to monitor the deposited energy of the scattered photons. Three of them have preamplifier gains chosen to measure single photon energies while the other two measure the energy of multiphoton bursts.

A movable lead absorber is installed in front of the silicon calorimeter to shield the detector against the synchrotron radiation from LSS1. Absorber thicknesses of $0 \div 5$ r.l. can be selected according to the beam intensity.

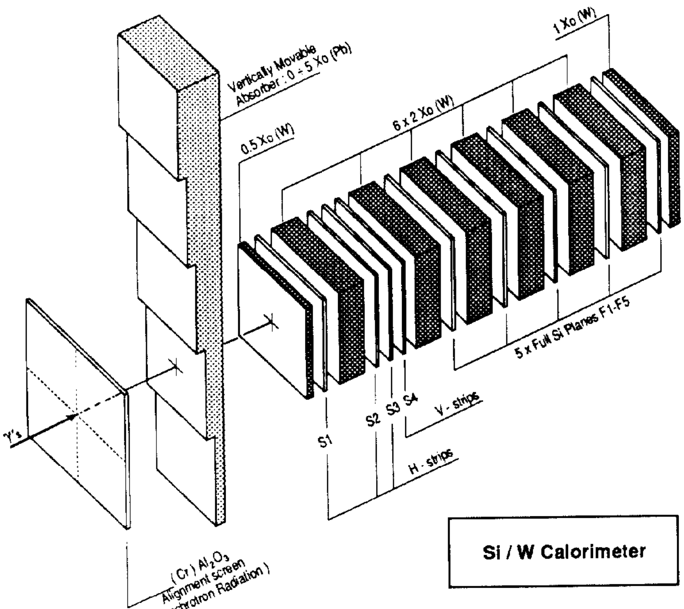

Figure 1: Schematic of the Si/W photon detector.

5 Data acquisition

The front end of the data acquisition system is based on a commercial VME board (CES8150) containing a Motorola DSP56001 Digital Signal Processor. Integrate-and-hold modules on a daughter board digitize the analog charges from the Si detectors by means of four ADC's. A 5 MHz sequencer on the DSP board controls the data flow from the daughter board to the DSP.

The data acquisition system has also been modified to improve speed and flexibility and data processing on each laser shot will be possible at a ~ 30 Hz rate.

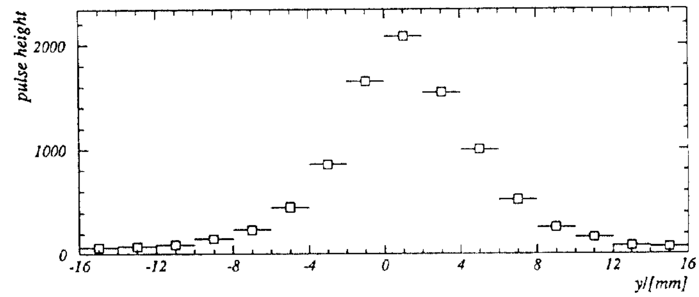

Figure 2 : Vertical profile of backscattered photons.

6 Commissioning results

Backscattered photons have been observed in the Si/W detector after e^- closed orbit correction at the LIR to steer the backscattered flux through the Al-window defining a $\pm 40\,\mu$rad vertical and a $\pm 110\,\mu$rad horizontal acceptance.

The optimum thickness of the lead absorber to reduce the synchrotron radiation flux was determined at a beam energy of 45.6 GeV.

The overlap at the LIR was optimized by varying the horizontal photon position and the synchronization between the laser pulse and the e^- bunch to the best signal at the detector. A typical vertical γ-profile at the $S1$ strip plane is shown in Fig. 2.

Special care has been devoted to the control of the polarization state of the laser photons. The *optical section* installed on a bench at the laser output was used to control the light polarization. A rotating $\lambda/2$ plate and a $\lambda/4$ plate can produce any elliptical light state, from linear to circular. Linear light has proved useful to the setting up of the polarimeter since in this case the Compton cross section does not depend on beam polarization (1). A "push-pull" $\lambda/2$ retarder introduces an additional π phase-shift, thus reversing once more the handedness. This provides a simple way to correlate the observed sign reversal in the measured mean-shift to the polarization signal.

The ellipticity of the light at the LIR was controlled in the optical section (Fig. 4) by timing the angular position of the rotating plate w.r.t. the laser pulse to compensate for depolarizing effects (reflections, birefringence etc.) from optical elements in the transport line which would spoil an initially perfect circular light.

The laser light is analyzed downstream the LIR by a combination of a $\lambda/4$ retardation plate and a dichroic polarizer. To evaluate the amount of circularly polarized light a two dimensional angle scan $(\theta_{\lambda/4}, \theta_{pol.})$ is used to determine the light minima and maxima. The measurement is done at the focus of a converging lens to avoid light intensity fluctuations from beam displacements. To be independent from shot by shot variations a non-polarizing prism splitter is used and the ratio of both light branches, with and without the plates, is considered for the calibration.

A new combined $\lambda/4$-polarizer analyzer for the laser optical section will be available for the '91 run period. A faster light polarization measuring system, where the intensity of the circularly polarized light measured after a rotating dichroic polarizer is independent of the rotation angle, will also be installed at the entrance of the LIR vacuum chamber.

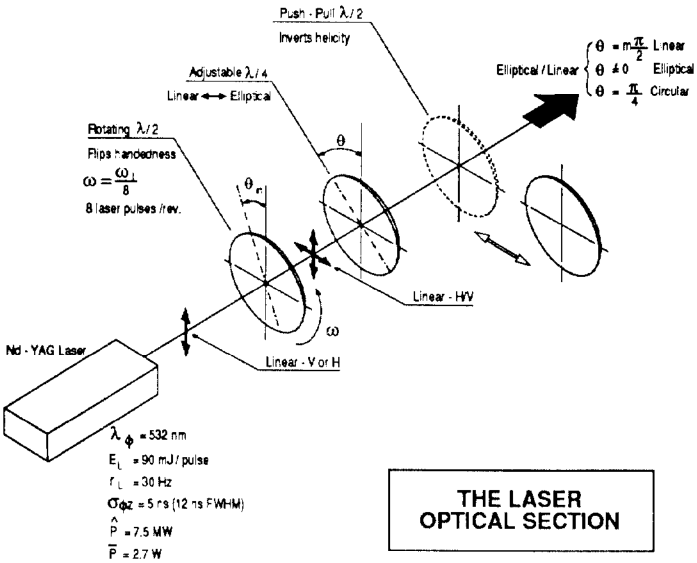

Figure 3: The optical section on the laser line.

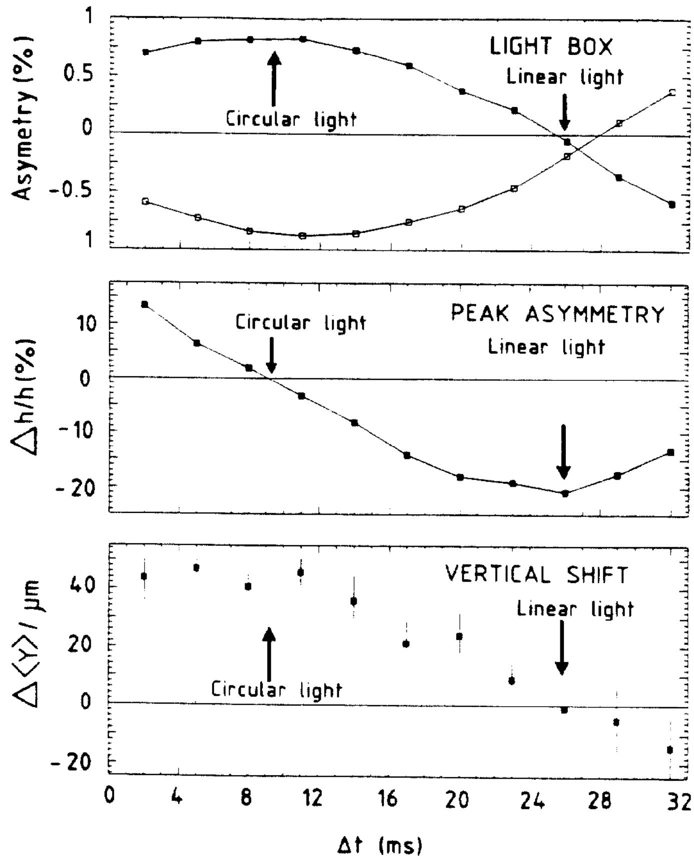

Figure 4: Degree of polarization of the laser photon states as a function of the arrival time Δt of the light pulses at the $\lambda/4$ plate.

7 Conclusions

The commissioning of the several components of the polarimeter has been carried on according to plans and with good results. Linear light proved extremely useful during the setting up of the polarimeter and the behavior of the instrument was found in agreement with the predicted performance.

The control and the optimization of the polarization states of the laser light was performed from the optical laboratory and the quality of the circular light was adequate to produce observable effects on the mean-shift of the vertical distributions.

Evidence of backscattered photons has been observed in the course of polarization-dedicated machine physics runs and first results on transverse polarization recorded [4].

8 Acknowledgments

The contribution and the skill of the many colleagues of the LEP Design office and of the LEP and ST workshops had a great impact in the realization of the polarimeter and we are indebted to them all.

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