Test Stand Measurements for an ILC Polarimeter

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The setup of two different small scale teststands for measurements regarding an electron Cherenkov detector as part of the ILC polarimeters is presented. Component measurements already carried out are analyzed and others, foreseen for the near future, are discussed. The larger one of the two teststands features the old Cherenkov detector of the SLD experiment, which will be used as a reference for a number of crucial measurements. Especially, the requirements for the non-linearity of the read-out chain are studied in greater detail and methods for its precise measurement before and during operation are being developed accordingly.

1 Polarisation: Measurement Principle

At the ILC it will be necessary to measure the beam polarisation with a precision of 0.25% to fully exploit the physics potential of machine and detectors [2]. These measurements will be realised via Compton polarimeters, where Cherenkov counters detect the backscattered Compton electrons. The Compton cross sections for different configurations of the laser light and e^+/e^- spin helicities are different, allowing for an asymmetry measurement, from which the polarisation level of the e^+/e^--beams can finally be determined. For the upstream polarimeter a special magnetic chicane (Fig. 1(a)) is envisioned, so that the Compton edge of the backscattered electron beam will always be at the same position in the Cherenkov detector regardless of the energy of the original electron/positron beam. Circularly polarised laser light is scattered off the e^+/e^--beams with about 10^3 interactions per bunch. The scattered e^+/e^- are then deflected by the dipole magnetic fields of

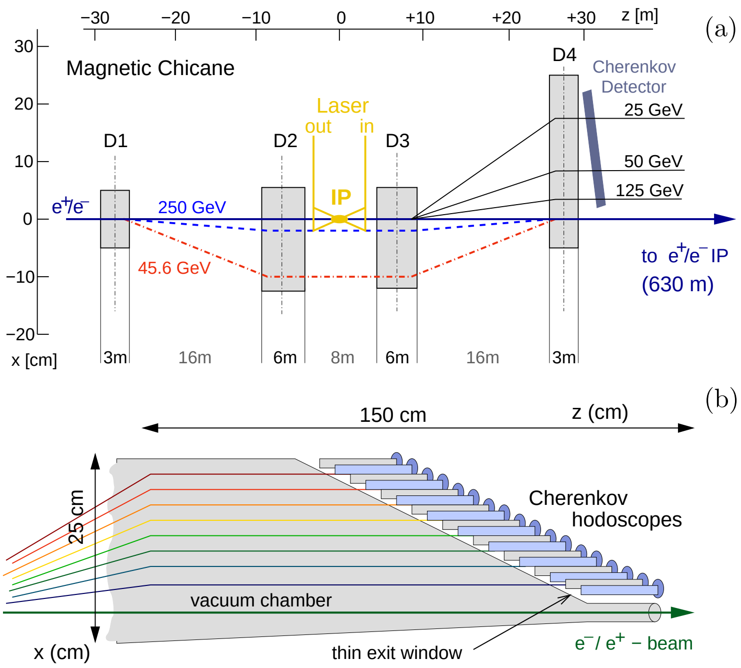

Figure 1: (a) The magnetic spectrometer and (b) the layout of the gas cherenkov hodoscope for the polarisation measurements.

the chicane and led to the detector, whose current baseline design [3] consists of gas tubes read out by photomultipliers (Fig. 1(b)). The incident e^+/e^- generate Cherenkov radiation inside the gas tubes, which is then detected by photomultipliers. However, alternative design possibilities, using quartz fibers and silicon photomultipliers, are also being studied.

For the detector R&D, many different aspects have to be taken into account and optimised. Among these are not only the choice of gas or the inside mirror-coating of the Cherenkov gas tubes (currently similar to those used for the polarimeter of the SLD detector at SLAC), but also different aspects of the photomultiplier and read-out electronics. It will, for example, be necessary to optimise the quantum efficiency, the sensitive area and the dynamic range of the photomultipliers, but also the reflectivity and the light extraction from the gas tubes. Furthermore, since the goal of achieving a polarisation measurement with a precision of 0.25% is very ambitious, the linearity of all detector components is extremely important. All non-linear effects (photodetectors, electronics, etc.) need to be measured precisely and corrected for if necessary.

2 The Component Test Stand

This test stand is based on CAMAC electronics and is used to develop different techniques for on- and off-line linearity measurements of various electronics components and different photodetectors. Up to now, two different methods for measuring the linearity of a QDC have been studied. The first method, of which Fig. 2 illustrates the setup, uses a sine wave as input to the QDC. The transition codes, or rather, the probability P_{code} for each transition to occur at a certain ADC-code is measured and compared to the response of an ideal QDC, see Fig. 3(a):

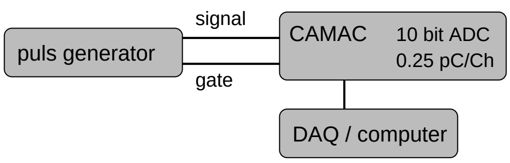

Figure 2: The setup for the electronics tests.

$$P_{code} = \frac{N_{meas}}{\pi \cdot \sqrt{\frac{A}{2}^2 - (code - offset)^2}},$$

where $A = 256$ pC is the charge amplitude at full scale range. Figure 3(b) shows the differential non-linearity (DNL), i.e., the difference between the measured and ideal QDC codes, while Fig. 3(c) displays the corresponding

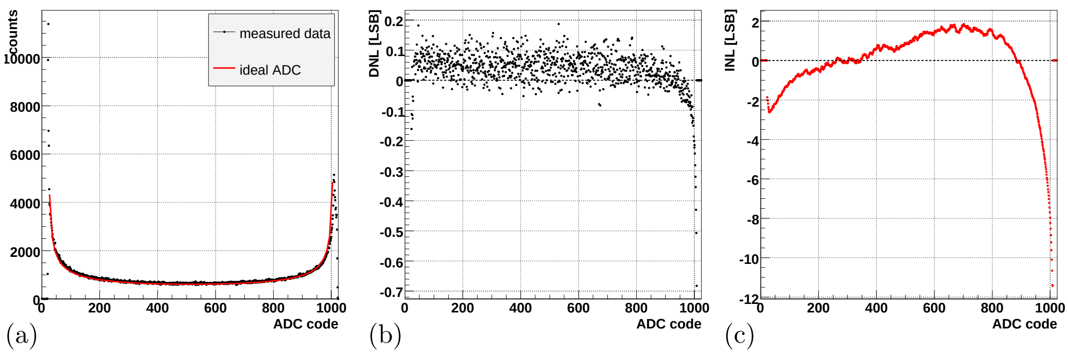

Figure 3: Linearity test: (a) measured and ideal prob. density function of QDC transition codes, (b) differential non-linearity, (c) gain and offset corrected integral non-linearity.

integral non-linearity (INL) after gain and offset correction, exemplary for channel 1. If a straight-line-fit is applied in the mid range of codes, from 200 to 800 ADC-counts, the INL ranges from 1 to 2 LSBs (least significant bit, or ideal QDC code width), corresponding to 0.1-0.2% of the full scale range.

The second method is a QDC self-test, integrated in the readout software. A DC-voltage from 0 to 20 V is applied to the QDC (1 V $\widehat{=}$ 12.5 pC) and the measured charge is compared to the input charge for multiple charge injections. This second method is less precise and, moreover, requires many steps and thus a very long measurement time.

In the near future, the component test stand will be used for a variety of other measurements, including the characterisation of different photo detectors (conventional PMTs and rather new developments, e.g. Silicon Photomultipliers), further linearity measurements regarding the photo detectors and, possibly, the entire readout chain. Longer term plans for this test stand also foresee measurements of temperature effects, the gain stability and other issues.

3 The SLD Cherenkov Detector Test Stand

As of early May 2006, the SLD Cherenkov detector is located at DESY. However, the necessary hardware components for its setup are not yet available, but a VME-PCI interface as well as charge-sensitive ADC (QDC) have been ordered. (For a description of the entire SLD-detector and the Compton polarimeter see Ref. [4].) For the detector commissioning it is planned to first test all nine channels for functionality – with a system of blue (and green) LEDs. Furthermore, the reflectivity and light yield ($\leftrightarrow$ geometry), the sensitivity of the photo detectors, and the light extraction from the gas tubes will be studied. Later on, temperature effects will also be investigated, which might lead to an active regulation / stabilisation via thermo-electric elements. A proposal from April 18, 2007 lists further planned measurements, that will serve as a reference for studying new design features. Each measurement will either be performed as component and readout test of a single channel or of the entire detector system (Fig. 4), including:

- the characterisation of different types of photomultipliers (regarding sensitivity)
  - ▷ dark rate / light response;
  - ▷ voltage and/or temperature dependence;
  - ▷ dynamic range / sensitivity;
- the Pros/Cons of different types of photo detectors and connecting fibers:
  - ▷ photo detectors: conventional PMs, APDs, and SiPMs;
  - ▷ fiber types: optical, wavelength-shifting fibers;
- and the analysis of different couplings: (direct, air gap, etc.) between gas tubes & fibers, and between fibers & photo detectors;
- Linearity / non-linearity measurements for different configurations

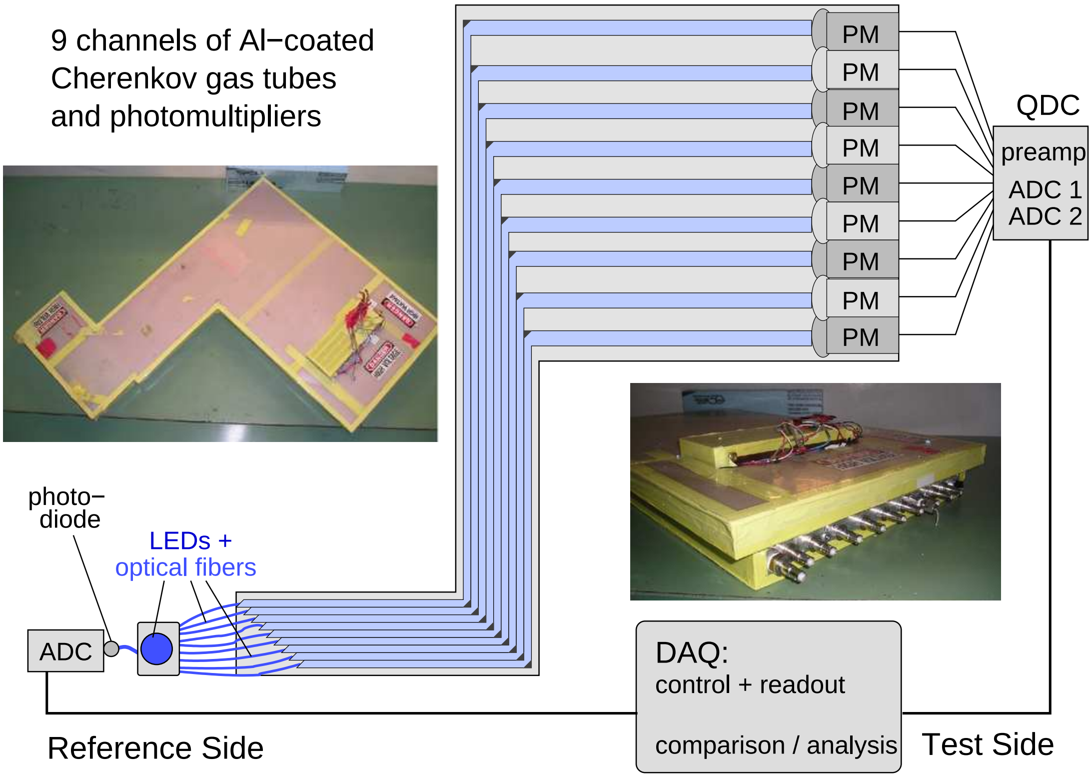

Figure 4: Schematic illustration of the setup of the old Cherenkov gas detector at DESY. The two photographs show a birdseye view (left), and the frontend (right).

4 Acknowledgments

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