detection of leaks. Complete analysis of the gas composition is performed by an automatic gas chromatograph station, routinely switched into the different circuits. Independently of the use of calibrated gases this instrument gives the different gas portions to an accuracy of ± 2 % of the measured value with an overall sensitivity of about 300 ppm [50, 51].

2.6.3 Electronic control and safety

The concept of the H1 gas system control follows the solution chosen for L3 time expansion chamber (TEC) [52, 53]. A Motorola 68000 CPU serves as a crate master, integrated into a VME-system with the necessary resources for monitoring, logging and control equipment. The instantaneous values of all analog outputs of the measuring devices, especially those for pressure and temperature, but also those for supply voltages are controlled within preset limits. Warnings or alarms are generated if one of the relevant parameter values is exceeded. In case of an alarm the gas circulation is stopped and the HV supplies of the detectors concerned are switched off. A computer independent hard wired logic with a more generous alarm setting protects the chambers against destruction in case of program failures or other accidents. In this case also an alarm is generated and the powerless open solenoid valves in the distribution rack on top of the electronic trailer connect the chambers with an argon flushed reservoir at atmospheric pressure as indicated in Figure 15. A set of four independent serial links per gas system monitors all gas parameters and distributes this information to the slow control system (see Section 6 of reference [1]).

Gas sensors are distributed in the H1 detector region, on the electronic trailer with the distribution rack and in the volume occupied by the trackers, as well as in the rooms where flammable gases are handled.

The tracker volume is flushed with $\simeq 12$ m^3 of nitrogen gas per hour to prevent accumulation of flammable gases in case of a leak. Since the operational pressure of most chambers is as low as 0.15 hPa relative to atmosphere and only 1.5 hPa in case of CJC, the amount of gas which may escape through a sudden leak in the chamber region is at most only a few liters. Small continuous leaks are best controlled in the closed loop circuits by measuring the pressure drop in the barrel over several days. The maximum working pressure in these circuits is limited to 1.6 bar absolute. A typical leakage of about 4 l/day corresponds to a pressure drop of $\sim$40 hPa/day. In the open circuits additional electronic flow controls, in series with FL1-1 and FL1-2, restrict the input flow. In case of a major leak the operational chamber pressure cannot be reached with the low flux adjusted by these controls.

2.7 Scintillators

Both scintillator arrays discussed in this section are located in the backward region (see Figure 3 of reference [1]) and have been installed to reject proton beam associated background at the first trigger level. The present life time of the stored proton beam in HERA during collisions varies between 10 and 48 h. The stored proton current design value is 160 mA with 2×10^{13} circulating protons in total. These protons are lost by beam gas and beam wall interactions producing background showers of energetic penetrating hadrons and halo muons. With a beam life time of 10 h the H1 sensitive detector volume is hit by this background with a frequency of 2.6 MHz.

2.7.1 Time-of-flight counters

The time of flight hodoscope (ToF) consists of two planes of 3 cm thick NE102A scintillator mounted perpendicular to the beam pipe upstream of the interaction region. Particles from proton induced background and from $e-p$ collisions are separated in time at this point by ~ 13 ns. The electron bunches have negligible size whereas the proton bunches are spread over 2 to 3 ns FWHM. The plane nearest to the interaction point (ToF1) lies at $z=-1.95$ m and has 16 butted counters, measuring 317×317 mm^2 thus matching the size of four BEMC stacks. The outer plane at $z=-2.25$ m consists of eight larger counters (317×634 mm^2).

In order to operate inside the 1.14 T field, ToF utilises 24 Hamamatsu R2490-01 high field photomultiplier tubes (PM). It is necessary to mount them perpendicular to the planes of ToF, requiring a light collection countersink to be machined into one of the large faces. A corresponding perspex truncated cone is glued to the other side to match the PM sensitive area. The PM's themselves are housed in non-magnetic holders and held in contact with the small light guide by springs.

Each wall of ToF is made up of a sandwich of scintillator and lead (Figure 16), mounted on a backing plate of non-magnetic steel to minimise stresses from the large magnetic field. The lead is 6.5 mm thick to absorb synchrotron radiation. Steel is used rather than aluminium to minimise eddy currents produced during a magnet quench.

The six inner counters (four on ToF1, two on ToF0) can be moved horizontally up to 20 cm from the beam pipe using computer controlled pneumatic rams. This removes them from the high radiation fluxes around the beam pipe during injection. With the counters in the open position, ToF can be split in half about the horizontal axis, allowing removal without breaking the vacuum in the beam pipe.

Signals produced by the PM's are amplified ($\times 40$), up to ~ 1 V before travelling down 29 m of cable to a NIM logic located in the electronics trailer. Here the signals are discriminated and strobed in three time windows: background, interaction and global, which are used in the first level trigger decision (see Section 5.3.1.1 of reference [1]) available after 250 ns. The device as a whole has a resolution of 4 ns, while individual counters have a resolution of the order of 2 ns. The timing information of all counters is available in the event readout chain.

The setting and width of the time windows greatly affects the performance of ToF, and they are continually updated as offline analysis proceeds. The background window currently starts 18 ns before the centre of the background distribution, and is 25 ns long. The interaction window starts 1 ns after the background window ends and is 13.1 ns long (Figure 17). A constant background of cosmic ray hits is present, about 200 entries per bin. Triggers in the interaction window are in fact much dominated by synchrotron radiation.

2.7.2 The veto wall

In addition to the ToF device two double scintillator veto walls are installed at a distance of 6.5 and 8.1 m, respectively upstream from the interaction point (see Figure 3 of reference [1]).

The smaller inner veto wall covers the near beam area (100×90 cm^2) down to a radius of 11 cm (Figure 16). The four scintillator pairs (NE 114, thickness 6 mm) are read via two photomultipliers (56 AVP, VALVO) each. The pairs are shielded against electromagnetic showers by lead walls of 4 cm thickness. Penetrating particles are then identified by coincidences between two scintillators with a time resolution of $\pm$ 3 ns. The large outer veto wall with an area of ca. 5×4 m^2 overlaps the inner veto wall and nearly all of the liquid argon calorimeter. The array of 10 counter pairs of up to 2.1×0.90 m^2 area each (Figure 16) is grouped around the last upstream HERA quadrupole with a 0.8×0.8 m^2 sized hole. The scintillators (NE 110, 1 cm thick) are coupled to 20 5 inch phototubes of type VALVO XP 2041. These tubes are shielded with thick iron tubes and μ - metal cylinders against the magnetic fringe field ($\approx$ 10 mT).

An iron wall of 5 cm thickness separates the scintillator pairs of the outer wall. The coincidence resolution of such pairs is $\pm$ 8 ns. It is dominated by the light path differences over the large area. The light attenuation length is measured to be larger than 1.5 m and leads to inefficiencies for the detection of minimum ionizing particles of $< 10^{-5}$. (see also references [54, 55, 56]). The time resolution achieved allows a clear time separation between the background of the passing proton beam and event correlated hits during e-bunch passing. A 3 m concrete wall separates the outer veto wall from the main detector and protects it against low energy showers from upstream.

Amplitudes, signal arrival times, rates and efficiencies of all counters are monitored online, and this information is used to study the background condition after each filling and during runs. The time of flight information allows to measure the z position of the $e - p$ interaction point online with a precision of ca. 30 cm. It is used in the first level trigger (see Section 5.3.1.1 of reference [1]), and is sent to the central data acquisition system for off-line analysis.