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Spacal Calibration and Maintenance

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Abstract

This note describes the various methods and techniques established to calibrate the Spacal and to maintain its operation. The emphasis lies on the documentation of the Spacal analysis and maintenance software developed so far within the Spacal Group. Possible future strategies to improve the existing methods are discussed where at hand[1].

1 Introduction

The lead/scintillating-fiber calorimeter 'Spacal' was installed in the H1-Detector in spring 1995 as one of the components of the H1 upgrade program [1]. It consists of two sections, i.e. an electromagnetic part with 1192 cells and a hadronic part with 136 cells. Detailed references and publications about the Spacal can be found in [2]. The Spacal allows to measure minimum ionizing particles, hadron showers and electromagnetic showers in the range between about 100 MeV up to the full electron beam energy of presently 27.5 GeV. Since maximum possible precision is required in order to increase the insight in deep inelastic scattering phenomena and the underlying QCD processes [3] the Spacal has been designed to have an excellent performance, namely an energy resolution of $\Delta E/E = 7.5\%/\sqrt{E} \oplus 1\%$, an absolute scale uncertainty of 0.5% at a linearity of $\leq 1\%$, a spatial resolution of σ_R=2 mm/$\sqrt{E} \oplus 1$ mm and a time resolution of $\Delta t \lesssim 0.4$ ns [1]. The objective of the Spacal maintenance and calibration is to reach these design performance values for the *in situ* and long term operation of the complete calorimeter. For this purpose various complementary adjustment procedures and calibration methods have been established.

[1]The note is designed as a reference manual for future Spacal maintenance. It stresses the technical approach rather than the underlying physics and is in parts most likely only understandable in connection with the described software. At the same time it is meant to give a starting point for future optimizations. It should be stressed that most of the routines and methods described in this note can not be run 'blindly' but require a minimum of physics considerations. I apologize for the extensive use of the so called 'H1 slang'.

This note is organized as follows:
In section 2 the energy calibration is described. Various calibration methods, namely with kinematic peak electrons, QED Compton events, π^0 mass reconstruction, halo muons, cosmic muons, LED/photo electron statistics are presented. One of the main aspects of the calibration is the investigation of the time behavior of the Spacal photomultiplier tubes (PMT) and the read out system. For the monitoring of the time behavior an LED System is used. In section 3 the basic features of the LED system are discussed in the context of its use for the energy calibration. The calibration corrections can be applied at different stages of the processing. In section 4 the adjustment of the PMT gains (HV) as well as the application of 'software' corrections is described. Furthermore the combination of data from several years is discussed. In section 5 the determination of the noise level and the calibration of the DSP are discussed before an outlook and summary are given.

For a detailed description of the time measurement and the TDC calibration we refer to [4]. The operation of the Spacal trigger and the determination of the 'ToF window' position have been described in [5–7].

A set of technical viewgraphes and instructions is given in an Appendix. The software developed in the framework of the Spacal Group up to November 97 has been collected and stored in a common place on the calorimeter disk `/shift/dice4/data29/h1/h1/spacal/softw`. An overview over the programs available is given in Appendix A. Appendix B shows the Spacal data flow as far as necessary to understand the calibration procedures and strategies. In Appendix C the HV settings used in 97 are tabulated. Appendices D-G contain technical instruction sheets for the acquisition of cosmic data, halo muon data and noise data.

2 Energy Calibration

A calibration procedure makes use of a 'normal' which serves as a scale reference. For example a test beam with known energy can be used to calibrate the calorimeter response. For the *in situ* energy calibration of the Spacal in the H1 environment more indirect methods must be used. In order to reduce systematic influences and statistic problems various complementary methods have been combined. The methods presented in the following provide multiplicative calibration constants for each Spacal cell.

2.1 Kinematic Peak Electrons

- Data: Standard *ep* data stored on 'Kinematic Peak Tapes' (containing events with electron candidates above 10 GeV, 17 GeV for the inner 255 cells) and DST. Subtriggers $s3$, $s4$ (used in 96 and 97)[2].
- Volume: $\gtrsim 30$ pb^{-1} would be necessary for the complete EM Spacal, i.e. $\gtrsim 50$ events in each of the Spacal cells.
- Purpose: Precision calibration for EM Spacal.

[2]Here and in the following all references to subtriggers follow the subtrigger definitions used in 96.

- Selection Algorithm: Hottest cluster between 23 and 30 GeV is the electron candidate. Cell wise determination of calibration corrections from mean electron energy distribution.
- Level of Precision: 0.5%-2% (depending on the algorithm used).
- References: [8], [9], [10], [11]

Method

The notion 'Kinematic Peak' (KP) denotes the strongly pronounced maximum observed around the electron beam energy of the energy distribution. As its name suggests the peak originates mainly from a kinematic effect, namely that for small angle scattering (i.e. sufficiently large $\theta_e \gtrsim 150°$) the cross section rises with approximately $1/[1-(E_e'/E_{e,beam})]$. Having a kinematic source the position of the maximum is to very good approximation independent of the behavior of the internal structure of the proton and can precisely be calculated without specific assumptions on the behavior of the structure functions. For the precise calculation of the shape of the measured energy spectrum the detector resolution and the detector acceptance as well as the angular dependence are taken into account using Monte Carlo simulations (MC). An uncertainty on the absolute energy scale at the level of 0.5% can be reached. The principles of the high precision energy calibration using scattered electrons is described in detail in [8]. Further calibration studies with scattered electrons in the Spacal using 96 data have been documented in [12].

For the purpose of Spacal maintenance a somewhat simplified procedure has been used which does not make direct use of MC simulations. A 'truncated mean' of the energy distribution is determined in an interval (typically between 23 and 30 GeV). Each event is assigned to the hottest cell of the electron candidate cluster. The calibration factor determined is proportional to the inverse of the mean of the total cluster energy distribution. For the determination of the absolute energy scale a 'mean normal' (proportionality constant) of 26.15 GeV is used for all cells. The cell wise calibration is extracted in an iterative procedure applying the calibration factors and recalculating the cluster energies. The iterations help minimizing the systematic bias which is introduced by the truncation of the mean, i.e. the restriction to a limited interval. The iteration procedure can be stopped as soon as the additional corrections resulting from the latest iteration are small against the statistical and systematic uncertainty. Iteration procedures are performed in a similar fashion in most of the calibration methods described in this note.

Data Acquisition

Separate Output Stream: In the years of 95-97 a separate data output stream has been used to collect kinematic peak events for calibration purposes (see fig. 1). Reconstructed events which satisfy a set of selection criteria described in the H1REC routine SPFLAG are copied to the tapes named as `/acs/data/9x/spacal/SPACKIN.C9xxxxxx`. On these KP tapes only the Spacal (i.e. SCLR, SCLP, SE0R etc.), BDC and CJC information are stored. All other event information is dropped. The reconstructed data are precalibrated according to the calibration corrections stored in the database (SCKP-bank).

Statistics: With the present luminosity the kinematic peak events are produced at an approximate rate of 5 Hz within the acceptance limits of the Spacal. Since the cross section drastically drops towards large radii (as $1/Q^4$), in most of these events the electron is scattered in the central region of the Spacal close to the beam pipe. To collect enough statistics in the outer region for the calibration of all cells of the Electromagnetic Spacal at the 1% level an integrated luminosity of ~ 30 pb^{-1} is needed.

Trigger: In 96/97 kinematic peak events were collected using dedicated subtriggers $s3$, $s4$ which are based on the Spacal IET trigger [5,6]. The energy trigger threshold were sufficiently high to minimize the (background-)rate. No vertex or track trigger conditions were imposed since in most KP events the hadronic final state escapes detection. The prescale factors were kept at minimum possible values. For radii above 20 cm usually no prescales were applied.

Data Analysis

The method described above was coded in two different software packages (see also Appendix A).

1. `softw/kp/kp1/`

   - Staging and reading data tapes and writing output files:
     `softw/kp/kp1/rec/GETKP.f` reads KP tapes and writes out a compressed calibration data file (Fortran sequential) for fast and easy handling of large numbers of events ($\sim$ 200 Bytes/event). Only the electron cluster information is stored.[3].

   - Filling of control histograms and calibration:
     `softw/kp/kp1/rec/HOTKP.f` is used for further selection and determination of cell wise calibration constants. The program allows the application of LED corrections and the investigation of their effect on the time behavior of the Spacal. Various versions of `HOTKP` are available (see `README`-files). `HOTKP-03.f` has the implemented feature to optionally allow automatic iterations. Make sure that the data formats match between `GETKP` and `HOTKP`!

   - Plotting histograms within the framework of PAW:
     `softw/kp/kp1/kumac/stab.kumac`

2. `softw/kp/kp2/` (also see:
`/shift/dice4/data29/h1/h1/spacal/calib/kp`)

   - a) Staging kinem. peak Tapes and writing output files:
     `softw/kp/kp2/rec/GETKPWEI.f` (see `GETKP.f` above).
     b) Reading DSTs and writing output files:
     `softw/kp/kp2/rec/GETKPHAD.f` reads DST and writes out compressed calibration data for the use in `HOTKP.f`. On DST the complete event information is available allowing to use the measurements of the hadronic final state for quality cuts and 'Double Angle Method' [8].

[3] The data volume is still rather large: In 1997 about 15 Million events were preselected corresponding to an integrated luminosity of 20 pb^{-1} yielding a volume of 3 GBytes. With this about 80% of the cells in the EM Spacal could be calibrated with kinematic peak electrons.

- Filling control histograms and calibration:
  `softw/kp/kp2/rec/HOTKPALL.f`
  Iterate to yield the final result.

- Plotting histograms within the framework of PAW:
  `softw/kp/kp2/kumac/[histo,navic20,navic3].kumac` produce all conceivable kinds of plots.

Remarks

As has been shown in the context of the F_2 analysis [8, 13, 14] the level of precision achieved with the method described above is approximately 1 to 2 %. Such a precision is not fully satisfactory for the physics analyses. However, with its simple approach the procedure allows to calibrate a large amount of data within a short time and is thus optimal for detector maintenance and initial calibration. Furthermore it allows the necessary extensive studies of the time behavior and the influence of the LED correction factors on the time behaviour (see section 3).

Better energy scale precision can be achieved using Monte Carlo simulations which allow to correct for variations of the dead material in front of the Spacal as well as the energy distribution shape dependence on the polar scattering angle of the electron (θ). Furthermore, studies on the Spacal homogeneity (i.e. detector response variations at the subcell level) are important to at this level of precision.

High precision studies are typically pursued in the framework physics working groups. The results should be made available to the Spacal group and the H1 collaboration on a regular basis.

2.2 QED Compton Events

- Data: Standard Luminosity runs, Subtriggers:
  L1: $s13$ (Energy in Spacal), L2: 21 TT (select events with two separate clusters, reject 'hot-spot' events)

- Selection: Two EM clusters in the Spacal which are coplanar ($E_1 > 12.5$ GeV, $E_2 > 4.0$ GeV, $20 < E_1 + E_2 < 32$ GeV, $E_{\mathrm{Spacal}} - E_1 - E_2 < 0.5$ GeV, $\mathrm{ECRA}_1, \mathrm{ECRA}_2 < 3.2$ cm, $E_{\mathrm{LAr}} < 2$ GeV, accoplanarity $\Delta\phi < 45°$), remaining detector empty.

- Duration/Luminosity: 4.5 pb^{-1} = $\sim$30000 events (in 96).

- Level of Precision: $\lesssim 1\%$

- Purpose: Calibration and linearity of Spacal EM, inner region.

- References: [15], [16]

Method

In elastic QED Compton events ($ep \rightarrow ep\gamma$ where γ has large transverse momentum) the energy of the outgoing photon and the scattered electron add to the electron beam energy. This type of events therefore provides a precise means to determine the calorimetric energy scale. In particular the absolute energy scale can be determined. Furthermore, since QED Compton events are kinematically overconstrained, the measured scattered particle angles can be used to predict the particle energies to first order independently of the energy calibration (Double Angle Method). QED Compton Events are therefore particularly suited for the calibration down to very low energies ($\sim$ 4 to 24 GeV) and consequently allow detailed studies of the linearity of the calorimetric measurement.

Data Acquisition

Standard data taking with $s13$ and L2 topological trigger mask (see above).

Data Analysis

Performed by the H1 working group 'Radiative Corrections'.

2.3 π^0 Mass Reconstruction

- Data: Standard Luminosity runs, 96: subtrigger $s50$ or any event with two photons in the Spacal.
- Selection: Events with two or more photons in the Spacal.
- Duration/Integrated Luminosity: 4 - 5 pb^{-1} in 96.
- Level of Precision: systematic: $\sim 4\%$, statistic: $\sim 0.25\%$ (inner region) up to 2% (outer region).
- Purpose: Calibration of complete EM Spacal.
- Reference: [17], see also [12]

Method

The first step is to evaluate an energy correction function to compensate for the loss of energy caused by dead material and the 15 MeV noise cut on each cell. The function can be determined as follows:
It is assumed that the Spacal is correctly calibrated, in general. The γ energies are subdivided into several (7 - 9) intervals, e.g. 0.3 - 0.45 ; 0.45 - 0.6 ; 0.6 - 0.85 ; 0.85 - 1.1 ; 1.1 - 1.35 ; 1.35 - 1.6 ; 1.6 - 2.0 ; 2.0 - 2.5 ; $\geq$ 2.5 ; [units in GeV]; Both photons are taken from the same interval. Then the invariant mass of the two photon system is calculated and histogrammed. The histograms are fit with Gaussians plus polynomials (for the background) and the mean

values of the fits are plotted against the mean values of the γ-energies of the corresponding interval $\langle E_\gamma^{int} \rangle$. Fit the resulting histogram with a function like:

$$f(E)_{\rm fit} = m_{\pi^0_{\rm PDG}}(1 - ae^{-E/b}) \tag{1}$$

and correct the energy as follows:

$$E(\gamma)_{\rm cor} = E(\gamma)_{\rm uncor} \frac{m_{\pi^0_{\rm PDG}}}{f(E)_{\rm fit}} \tag{2}$$

The corrections iteratively converge against unity for energies higher than 4 GeV. For more details see [17] (page 44) and [12].

The second step is to work out calibration constants for each individual cell:
The full information of the DCLU bank is used to calculate the cluster energy for all cells. Fix one cell(number) and require that it is the hottest cell of a cluster in an event. Combine with all other clusters of the same event to determine the invariant mass $m(\gamma\gamma)$. Fit the resulting histogram with a polynomial plus a Gaussian and build the correction constant[4] as follows:

$$c = \frac{m(\pi^0)_{\rm PDG}}{m(\pi^0 \to \gamma\gamma)_{\rm Fit}} \tag{3}$$

Perform the above procedure for all 1192 cells this way obtaining the first set of calibration constants. Typically 75 - 2500 entries are found in the π^0-mass peak and the signal to noise ratio is approximately 9 to 1. Due to the fact that a cluster normally consists of more than one cell, further iterations have to be performed because when determining the first set, it is assumed that a cluster consists of one cell.

Second iteration: Evaluate the *new* cluster energies as in the first iteration considering the first set of correction constants (for each cell in a cluster). The constants worked out are multiplicative, and a third iteration (and eventually a fourth one) considering the first two (three) sets of constants should be worked out. For more details see [17] page 47.

Data Acquisition

Data needed in the n-tuple: vertex information, EM Spacal: x, y, z − position, number of clusters per event, number of cells in a cluster, cluster radius, geometric numbers and energies of each cell in a cluster and the info to which cluster a cell belongs. HAD Spacal: x, y, z − position, energies.

Data Analysis

Cuts applied: $E_\gamma \geq 350$ MeV, $R_{Clu} \leq 2.75$ cm, $\frac{E_{had}}{E_{em}+E_{had}} \leq 0.025$, $\frac{\#Cells}{Cluster} \geq 4$, $\frac{\#Cluster}{Event} \leq 20$, -30 cm $\leq$ z-vertex ≤ 30 cm, 10 cm $\leq d_{Beam}^{Cluster} \leq 75$ cm. A selection of programs can be found under: `softw/pi0`. A short letter of instruction is located in the file `README`.

[4]Here again it is assumed that the Spacal is correctly calibrated on average.

2.4 Halo muons

- Data: Dedicated Halo muon Runs (proton or colliding beam) with dedicated EM + HAD coincidence trigger, Lowest possible thresholds (sum of 4×4 cells within one IET array: ~ 100 MeV level), see also Appendix E.
- Selection: Coincidence Finding in the Spacal, Inner Region excluded.
- Duration: $1 - 6$ h
- Level of Precision: $\sim 5\%$
- Typical Purpose: Relative calibration of HAD Spacal and outer EM Spacal.
- References: [18], Appendix E
- Remarks: Further developments using track chamber information necessary.

Method

Halo muons are produced in decays of secondary particles (π) from proton beam-gas or beam wall interactions. They traverse the H1 detector horizontally and are correlated in time with the proton beam (AToF). On average about 350 MeV are deposited in each section. The rate of halo muons increases towards small radii. However, the background overproportionally increases so that the selection on Spacal information only becomes rather difficult. The basic methodical principles have been described in [18] in the context of an analysis using the instrumented iron for event and track selection. The algorithm and software presented here relies on Spacal information alone.

Data Acquisition

Halo muon data have been recorded in special runs with stable protons (e.g. during the time when the e-beam is filled and ramped).

Data Analysis

The software using the Spacal only is stored in `softw/halo/rec/spanal`. The software making use of the instrumented iron can be found in `softw/halo/rec2`.

2.5 Cosmic Muons

- Data: Dedicated cosmics runs (no beam) with dedicated subtriggers $s118$, $s119$ (see also Appendix D), lowest possible thresholds (sum of 4×4 IET arrays: ~ 100 MeV level).
- Selection: Cosmic muon track finding in Spacal.
- Duration: Few hours data taking + 0.5-1 day analysis.

- Level of precision: $\sim 4\%$
- Purpose: Relative calibration of HAD Spacal and outer EM Spacal.
- References: [19], [20], Appendix D.

Method

Minimum ionizing cosmic muons, vertically traversing the Spacal (i.e. 4 cm corrected path length/per cell) deposit an average energy of approximately $\sim$ 35 MeV per cell[5]. The low noise level of the Spacal ($<$ 3 MeV) allows not only to precisely measure the deposited energy in each individual cell, but also to trigger on cosmic muons independently of other H1 subdetector components at a very good efficiency ($\gtrsim 80\%$).

For the energy calibration the measured cosmics events are selected using a track finding algorithm which demands minimum energy deposits above the noise in a number of cells in a row and at least two cells within a line in the neighborhood of the cell considered. Detailed descriptions of the data selection algorithms can be found in [19, 20].

Data Acquisition

The optimal condition to record cosmics is when there are no particle beams in HERA. Technical instructions how to record cosmic data can be found in Appendix D. An alternative way to record cosmic data is to demand coincidence of the Spacal cosmics triggers with a track in the muon barrel (subtriggers $s110$ to $s113$).

Data Analysis

Two software packages have been developed. Both include reading of the raw data from tape, data selection, production of ntuples and histograms using raw data. The raw data are reconstructed using the standard H1REC reconstruction routine `sscale` but *without* application of offline calibration constants (SCKP) or LED corrections (SLED) (see `spreal.f`)[6]. Correction factors are determined for each cell from the relative positions of the cosmics energy spectra. The two packages slightly differ w.r.t. the selection algorithm. The algorithm coded in `softw/md` is well established and documented in [19] and `softw/md/README`. It is relatively slow and produces large data output. The algorithm coded in `softw/cosmic` is newly developed following a selection algorithm described in [20]. It has (partially) been documented in `softw/cosmic/note_ca.ps`.

1.`softw/cosmic`

1. Program to read and select raw data and to produce ntuples:
   `softw/cosmic/rec/spanal`

[5]The value given here has been measured using the absolute scale calibration from kinematic peak electrons, assuming perfect linearity of the Spacal.

[6]Note that for comparisons of results from cosmics with results from kinematic peak data it is necessary to take the possibly different precalibrations into account.

2. Source code in `softw/cosmic/rec/ftn/*.f`

3. Paw Macro to produce histograms (1 file per ntuple) and correction factors:
`softw/cosmic/kumac/add_cosmic_ntp.kumac`

4. Paw Macro to accumulate statistics using several histogram files and to produce correction constants:
`softw/cosmic/kumac/add_cosmic_histo.kumac`

2.`softw/md`

1. Program to read and select raw data and to produce ntuples:
`softw/md/ntup/ntup`.

2. Program to select cosmic events and to display events:
`softw/md/evd/evd`. This program produces ps-file output in `fort.27`, histogram output in `md/data/*.his`.

3. Program to produce plots and correction constants:
`softw/md/kumac/evd.kumac`

Remarks

Iterations: Various techniques to determine the exact position of the measured asymmetric, Landau-shaped energy distribution of the cosmics have been investigated. Comparisons of the results with the results from kinematic peak electrons have shown that the use of the arithmetic mean (truncated, i.e. restricted to the interval 5-100 MeV for the EM Spacal and $\sim$ 15-300 MeV for the HAD Spacal) provides the most precise results. In particular for low statistics data samples and for badly adjusted cells with large corrections the results of the fit routines tend to be wrong. The truncation of the energy distribution for the determination of the mean systematically biases the result of the calibration algorithm. The error increases with the size of the correction factor. It is therefore advantageable (similar to the KP analysis) to perform a number of iterations in which the input energy scale is adjusted step-by-step. The iterations should include the event selection. Usually, the additional corrections should be small after two or three iterations.

Problematic cells:

The calibration with cosmic muons also allows to detect problematic or dead cells by inspection of the relation between the mean and the width of the distribution using calibrated data.

Track reconstruction: The selection of sufficiently long tracks in the Spacal allows to precisely measure the x-y inclination of the cosmic tracks while the z position is unknown. Future studies using track chamber information may investigate whether the precision can be improved when taking the z-position as measured in the neighboring track chambers (BDC, instrumented iron) into account. In this context the influence of muons which do not cross the whole Spacal but deposit their complete energy in the Spacal and this way loose the properties of minimum ionizing particles could be studied. There are further non understood features of the cosmics analysis, e.g. the absolute scale. Calculations of the average energy deposit (using the Bethe-Bloch Relation) somewhat disagree with the measurements. The source of the discrepancy is unclear.

In summary, the use of cosmic muons provides a strong means to calibrate both the EM and the HAD Spacal. Together with the analysis of kinematic peak electrons it has been used successfully as the main method for the first round Spacal calibration during the data taking. The sharpening of the method with the objective to significantly improve the precision as explained above is possible without too great an effort. Technically, it is necessary to further 'streamline' the software and to implement features like an automatic iteration procedure.

2.6 LED Photo Electron Statistics

- Data: LED pulsed events (stand alone or central DAQ).
- Duration: About 2 hours of data taking and half a day for data analysis.
- Level of Precision: $\sim 15\%$.
- Purpose: In situ adjustment of newly implemented PMTs or fast functionality checks during the reinstallation of the Spacal after the shutdown.
- References: [9], [21]

Method

The method of the LED photo electron statistics provides a fast and simple way to coarsely (15-20%) equalize the gains of the photomultiplier tubes (PMT). A description of the method as well as a few illustrating figures can be found in [9]. The gain of a PMT is given by the relation $G \propto \frac{d\sigma^2}{d\langle A\rangle}$ which can be derived from $\langle A\rangle = GN_{e^-}$ and $\sigma^2 = G^2 N_{e^-}$ where $\langle A\rangle$ and σ^2 are the mean and variance of the response of the PMT anode respectively. N_{e^-} is the number of photo electrons produced at the photo cathode. Using this relation the gain of a PMT can be measured by stepwise varying the intensity of the input light.

The Spacal LED system provides a variable source of light. An LED ramp typically consists of 4 to 8 steps of different pulse lengths[7]. A description of the Spacal LED System can be found in [21]. At each step 500 to 1000 events are accumulated in order to minimize the statistical error and possible influences from background[8].

For the analysis the mean $\langle A\rangle$ and the width σ for each step and each cell are determined by a Gaussian fit to the distribution of ADC counts. After subtraction of the pedestals the values for each cell can be plotted in the form σ^2 versus $\langle A\rangle$ which are fitted by a linear polynomial. The slope of the fit is proportional to the gain and the relative calibration value for each cell is given by its inverse.

[7] A variation of the LED Voltage is also possible but not recommended since the step width when changing the voltage is comparably small.

[8] Larger numbers of events will cause data storage problems on the local disk.

Data Acquisition

There are two alternative ways to take the LED ramp data, the stand alone option and the standard central DAQ. In the following the basic steps of the stand alone option are described which is performed from the OS/9 station `h1cal10`.

- Take the Spacal out of the Central Read Out.
- Go to the roof of the electronics trailer. Reboot the `h1cal10` and login as `daqbis`. Start the program 'Spider'. Disconnect LED trigger LEMO cable on the back of the LED pulser and connect the stand alone LED trigger cable[9].
- Choose pulse length (0-7) and pattern 31[10] on the Spider menu. Enter the menu Calibration Run. Set the DAC value to 1 and choose the frequency 170 corresponding to about 10 Hz. Enter the Run Menu. Choose number of events, record, runnumber and transparent format for ADC and TDC.
- Perform the run. Change the pulse length after each step. Take a pedestal run (pulse length 0). A run of 500 events has a size of 6.5 MBytes. Transfer the data to the UNIX environment via `ftp`.

Data Analysis

Available Programs:

- `softw/anabis/ana`
  Production of ntuples from spider-stand-alone-rawdata. The format of the ntuple is based on the hardware mapping of the readout. For each analogbox one ntuple is produced. Since each of the 128 channels of an analog box are split into two ADC channels, 'gain1' and 'gain4', each ntuple contains 256 variables. In addition an event counter is written for each event. Copy all files in `softw/anabis` into your own directory and set the directory paths in the code correctly before compiling and linking. Also see the `readme` file.
- `softw/equi/check.kumac`
  Production of analogbox wise tables containing σ and $\langle A \rangle$ values.
- `softw/equi/ledfit.kumac`
  Fitting σ^2 versus mean of A, determining and plotting the measured gains[11].

[9] In case of problems ask for help from the hardware expert.

[10] 31 consists of 5 bit 1 states. By pattern 31 all 4(5) LEDs of a Supermodule will be activated. For the hadronic Spacal and the Backward Plug pattern 3 or 12 is more convenient.

[11] Note that the inverse of these values is proportional to (multiplicative) calibration factors.

3 Time dependence and LED Corrections

In addition to the intrinsic detector resolution the *long term*[12] time behavior of the Spacal is one of the dominant sources which limit the actual energy resolution achieved in the experiment.

It is useful to distinguish between time dependences or instabilities of individual cells and global changes common to all cells in a similar way. Individual cell time dependences caused by PMT gain changes are expected at the level of up to 5% per year [21]. These so called 'drifts' are typically slow and continuous. In contrast global instabilities are due to changes of the Spacal environment (e.g. temperature, noise, baseline etc.). The most noticeable common changes (at the level of 0.5 to 1%) typically occur abruptly in connection with power failures of the H1 electricity net.

The gain behavior of each individual PMT is monitored by the LED system. LED corrections are automatically calculated and applied to the physics data during the event reconstruction (see also Appendix B). Experience has shown that it is vitally necessary to carefully control and monitor the behavior of the LED system in order to avoid the application of corrections which do not really describe the time behavior of the Spacal and which would inevitably spoil the quality of the data. As a matter of fact the control of the LED corrections has been and continues to be one of the main topics of the work on the Spacal energy calibration.

While the individual cell behavior can be monitored best using the LED system the overall changes can more reliably be investigated using physics data, e.g. kinematic peak events. It is important mentioning that cell wise time dependence studies using the kinematic peak are possible only in the central region of the electromagnetic Spacal where the event rate is sufficiently high. However, calibrated kinematic peak events can be used to investigate the time behavior of the Spacal response before and after application of LED corrections. The position and shape of the kinematic peak is a reference allowing to compare the time behavior with and without LED corrections (also see section 2.1).

4 Application of the Calibration Results

By application of the calibration results the quality of the already recorded data as well as of future data can be improved. For the recorded data offline corrections are applied during the reconstruction of the data (e.g. reprocessing) or in the physics analyses. For the improvement of future data it may be useful to adjust the PMT gains by changing the High Voltage (HV). Changes are in particular necessary to adjust the PMT output signal to the available ADC range and for the equalization and sharpening of the trigger thresholds. Note, however, that any HV change introduces instabilities. It is therefore not recommended to change the HV setting during a data taking period (see also [9]).

4.1 HV Adjustment

The gain G of the photomultiplier tubes (PMT) and the applied HV U are related approximately via $G \propto U^6$. Thus, the relation $U_{i,new} = U_{i,old}\ c_i^{1/6}$ describes the new set of High

[12] Short term fluctuations occurring at a time scale of less than 3 minutes can not be monitored.

Voltages where $U_{i,old}$ is the set of old High Voltages and c_i are the calibration constants. In the following a description of the HV steering hardware and software is given followed by an instruction on the usage of software for the calculation of HV and the production of steering files. A more detailed description of the HV adjustment can be found in [9].

HV steering

The Spacal HV System consists of one Power Supply and 84 programmable HV Distribution Boards each of which is connected to 16 Spacal cells. The CAEN Power Supply provides the Distribution Boards with High Voltage. The Distribution Boards reduce the voltage individually for each cell by up to 350 Volts. The channels for the BPLUG and the radiation monitor are directly connected to the CAEN Power Supply. Due to this separation of the voltage system steering and monitoring of the High Voltage is done at two different OS/9 stations `h1cal5` and `h1cal10`, `h1cal6` respectively.

- The OS/9 station `h1cal5` is used to control and monitor the HV Power Supply CAEN. The voltages of the different channels are defined in a file called `hv_spacal_on` on the account `hv_spacal`. The program `spacal_hv` monitors the currents and voltages drawn by the CAEN and performs automatic resets in the (rare) cases of HV trips. In addition it offers a menu to turn the voltages on and off.
- The High Voltage Boards are steered via a serial bus. The reduction is defined in the file `shvr.txt` on the OS/9 stations `h1cal6` (account `hera`) and `h1cal10` (account `warmstart`) for standard Central DAQ running and stand alone running, respectively. The `shvr.txt` reduction values range from DAC 0 to DAC 255 which translates to reductions between 350V (DAC 0) and 0V (DAC 255), with a step width of about 1.4V.

HV calculation and production of steering banks

A program to calculate new voltages on the basis of correction constants and to produce new HV steering banks is available on `dice2`. A list of relevant files is given below:

- `softw/anabis/scngijhv.pd` contains the mapping of the cell numbers to the high voltage channel numbers.
- For reference you find the source codes in
  `softw/hvcalc/hvcalc.f`
  `softw/hvcalc/hvcalcread.f`
  `softw/anabis/scngread.f`
  and the executable `softw/hvcalc/hvcalc`.
- The program is run by executing the shell script
  `softw/hvcalc/hv.x`.
  Inside `hv.x` the input (used for data taking) and output (new, calculated) HV files as well as the file containing the gain corrections are defined. Five files must be specified inside the script `hv.x`:

- Input file containing the correction constants[13].
- Input file containing the reduction factors of the old set of HV[14].
- Input file containing the CAEN voltages of the old set of HV[15].
- Output file name for the new reduction factors to be calculated.
- Output file name for the new CAEN voltages to be calculated.

Perform the following steps:

- Copy the two HV steering files from the two OS/9 stations `h1cal10` and `h1cal5`, rename and archive them [16].
- Specify the names of the five files in `hv.x`.
- Calculate new HV and produce new steering files by typing `hv.x 1 nnn 1` where `nnn` is the number of the new HV-file-version[17]. The program writes any action to a logbook file called `RECORD`.

Activating the steering files

- Copy the new file `spacal_hv_on` to OS/9 `h1cal5` using `ftp`.
- Copy the new file `shvr.txt` to OS/9 `h1cal10` using `ftp`.
- Telnet `h1cal10` and login `daqbis` password `daqbis`. Never login as `warmstart`!
- Copy the new file `shvr.txt` to the directories `/h0/USER/warmstart` `/h0/USER/cosmic` `/h0/USER/daqbis/input` and `/h0/USER/daq/input`.
- Type `cb` in order to produce a binary bank, `Create SHVR`, `exit`.
- Telnet `h1cal6` (account `hera`). Type `cd calib` and find the file `shvr.bos`. This is the file used up to now for standard running! Archive it now, otherwise you can not perform the following step!
- After archiving type `ftp h1cal10`, `daqbis`, `daqbis`, `bin`, `get shvr.bos`. The transfer does not work if the old file `shvr.bos` still exists.
- The new file will be activated at the next warmstart.

Be sure that you archive the old and the new files such that you can safely retrieve them if necessary. All HV-files used so far and a file called RECORD can be found in `softw/hvset/`.

[13] Prepare a file with two column and 1348 lines containing cell numbers and correction factors.

[14] corresponding to file `shvr.txt` used for the calibration data

[15] corresponding to file `spacal_hv_on` used for the calibration data

[16] Archiving means the storage of used files and the bookkeeping. It still has to be done manually, see `softw/hvset` where the archive is located.

[17] The message 'HV range problems' indicates that some manual work might be necessary.

Remarks

One of the main disadvantages of the Spacal HV system in its present realization is connected to the fact that the CAEN power supply and the HV reduction boards are not controlled from the same source. While the CAEN power supply is controlled and monitored from the OS/9 `h1cal5` via a stand alone bus connection the HV reduction boards are included in the general warmstart procedure. This decentral structure makes it difficult to further develop and automatize the HV adjustment software. In the following the two most important developments to be possibly realized in the future are mentioned:

- An HV adjustment and monitoring program running in the framework of the SPIDER software on the OS/9 station `h1cal10` would make the determination and loading of new HV settings much easier. The realization requires the use of the LED system (to measure the PMT gain changes) in connection with SPIDER and the communication of the OS/9 `h1cal10` with the OS/9 `h1cal5` from which the CAEN power supply is controlled. As the input to such a program a set of gain correction (calibration) constants derived from the data analysis are required. Starting with the old HV settings the program iteratively calculates and loads new HV settings. The LED system is used to measure the achieved gain change. The difference between the achieved and the intended gain change gives then the starting point for the new calculation of HV settings. The procedure converges as the achieved gain change approaches the intended gain change. It is finished when the achieved gain change for each of the cells is equal within the accuracy of the system. Note that the range of 350 V for each HV board limits the gain range available. This feature will complicate the realization of the procedure sketched above.

- The archivation of the old HV settings could be automatized. Presently the HV settings are numbered and stored in `softw/hvset` by hand. The manual treatment costs time and implies the risks of mistakes. A proper archivation may become relevant in the future in particular when data from different years and HV settings must be combined (see also 4.3).

4.2 Application of Off-line Corrections (SCKP)

During a data taking period it is preferable to apply off-line corrections rather than HV corrections because the influence of off-line corrections is directly calculable while a change of the HV introduces instabilities which must be monitored using the LED system. The best way to apply off-line corrections is to load correction constants into the H1 database bank SCKP[18] (see also Appendix B). Since both L4 and L5 make use of the SCKP bank the preferable time to apply the corrections is between two luminosity fills when the database for both systems can be accessed.

[18] There are several additional banks which allow application of constants. For bookkeeping reasons it is highly recommended to use one single bank for all corrections.

Technical Procedure

- Prepare the set of correction files to be loaded in the correct format: The file must contain a header (3 lines) followed by 1348 rows of correction constants. The file must have exactly 1351 lines and 1 column. An example file can be found in `hvcalc/outfiles`

```
SCKP
1
1348
1.00000
.
.
1.00000
```

- For consistency between L4 and L5 it is highly recommended to activate a new calibration starting with a run number which is between two luminosity fills so that the calibration can be activated for L4 and L5 at the same time.

- Wait until the respective luminosity fill is finished. Ask expert to fill database.

- Call H1 control room and ask the shift crew to reload the newly filled database onto the filter farm.

4.3 Long Term Calibration and Combination of Several Year's Data

So far the Spacal data have been calibrated on a year by year basis. The experience of the commissioning year of 95 has taught that a change of the HV settings should be performed as rarely as possible since each change introduces instabilities which are hard to monitor. Consequently, in the years to follow, 96 and 97, the standard HV setting was changed only in the beginning of the year. The corrections are typically small. However, the changes are necessary to adjust the pulse heights to match the ADC range available and to provide sufficiently sharp trigger thresholds.

In the long run the data from various years will be combined. The calibration of the combined data will probably be somewhat difficult in particular in the outer region of the Spacal where the number of scattered electrons per year is so small that a year-by-year and cell-by-cell high precision calibration is not possible. It is therefore necessary to further develop calibration methods which provide higher statistics also in the outer region (e.g. π^0 calibration) in order to achieve a precise year-by-year calibration of the data. Furthermore the knowledge of the HV settings can help to equalize the gain of a given cell between different years.

The use of the LED data or the LED corrections for the long term calibration requires further studies of the stability of the system between the different years. Firstly, the running conditions of the LED system have changed from year to year and the stability of the reference photo diodes has not been investigated in sufficient detail. Secondly the optical coupling of the LEDs to the PMTs which is not monitored by the photo diodes is somewhat fragile and may have changed due to mechanical influences during the shutdowns.

5 DSP Calibration, Determination of the Noise Level

The regular determination of pedestal and noise is important for various reasons. First of all changes in the behavior of the detector must be detected. In general, changes indicate either problems in the electronics or changes in the environment. In both cases it is important to trace the source. Furthermore, an undetected shift of the pedestal has an influence on the scale of the energy. A wrongly determined noise level may lead to an inefficient data compression and thus an increase of computing time per event.

Once the pedestal and noise are known the information can be used to compress the data (zero suppression). In the case of the Spacal, DSP (Digital Signal Processors, see also fig. 1(a)) are used to perform the zero suppression. In the ADC branch the pedestal is subtracted. For each cell the energy value is accepted only if the value is larger than the given noise threshold. The accepted cells and energies are used to produce the raw energy bank 'SRCE'. For correct and efficient zero suppression it is important to determine the position of the pedestals and the noise on a regular basis. Precision is necessary in order to minimize the influence on the energy measurement.

Data Acquisition

For this purpose a standard procedure has been developed which is called DSP Calibration. Appendix G contains instructions on how to perform a DSP calibration.

Another motivation to record noise data is the use of such data for Monte Carlo simulations of the detector behavior. In Appendix F instructions are given how to record noise runs for monitoring and simulation purposes.

Remarks

In the past the DSP calibration has been performed manually. Every week or ten days a person has to go to the hall and follow a standard procedure (see Appendix G). It is conceivable that in the future the procedure becomes partially or completely automatized. As a first step it would be convenient to modify the procedure such that the DSP calibration can be performed by the shift crew in between the luminosity fills.

6 Summary

In summary, complementary methods developed and used for the energy calibration of the Spacal have been presented and technical descriptions of the corresponding data analysis software have been given. The Spacal calibration is and continues to be of major interest for physics analyzes in the kinematic region at $Q^2 \lesssim 100$ GeV where the bulk of the HERA data is situated. A precise energy calibration becomes more and more important as the systematic sources of uncertainty become more and more relevant with increasing statistics. The two methods regularly used for the initial calibration in the framework of the Spacal Detector Group are the method of kinematic peak electrons and the method of cosmic muons. With these methods an accuracy of the absolute energy scale at the level of 1-2% has been achieved for the initial calibration This initial calibration has given the starting point for the fine (and final) calibration which is performed by the physics working groups for a selection of high quality data using Monte Carlo simulations. In addition to the regular maintenance of the Spacal the main future efforts should be made in the following three fields:

- The further development of the calibration methods should be pursued mainly with the aim to reach a better precision in the outer region of the Spacal where presently the statistics limits the precision of the energy calibration.
- The detector response and stability should continuously be monitored and improved. The focus should be put on improving the accuracy of the LED system. This should allow to monitor the time behavior at the level of 0.1%.
- Last but not least the calibration results of the physics analysis working groups should be collected and made available to the H1 community on a regular basis.

Acknowledgments

The work in the SPACAL group during the last three years has been a rich and exciting experience. For this I would like to thank all the members of the Spacal group. Especially I would like to thank E. Tzamariudaki who it was a pleasure to work with and who has a great part in producing this note. Explicit thanks also to C. Arndt, C. Müller and R. Stamen for their contributions.

Appendix

A Collected Software Overview

All software has been collected in the directory `/shift/dice4/data29/h1/h1/spacal/softw/` abreviated as `softw/` above. The functionality of most of the stored programs has been tested. It is however recommended to check the logics of the event selection and and to adjust the input/output directions before running.

`anabis`	make RWN ntuple from spider data
`cosmic`	cosmics (1)
`cosmic/rec`	
`cosmic/rec/ftn`	cosmics source codes
`cosmic/kumac`	cosmics paw kumacs
`cosmic/data`	
`equi`	LED photoelectron statistics
`halo`	
`halo/rec`	
`halo/rec/ftn`	halo source codes (Spacal only)
`halo/rec2`	halo source codes (Spacal and inst. iron)
`halo/kumac`	halo paw kumacs
`halo/data`	
`hvcalc`	HV calculation and bank production
`hvcalc/outfiles`	
`hvset`	'archive' of hv steering banks
`kp/kp1`	
`kp/kp1/rec`	kin.peak software (1)
`kp/kp1/kumac`	
`kp/kp1/kpout97`	correction factors applied to DST1.C97
`kp/kp1/data`	
`kp/kp2`	
`kp/kp2/rec`	kin.peak software (2)
`kp/kp2/kumac`	
`kp/kp2/data`	
`md`	cosmics (2)
`md/evd`	
`md/evd/ftn`	track finding and selection code
`md/data`	
`md/ntup`	
`md/ntup/src`	produce ntuple from RawData source codes
`md/kumac`	calculation of correction factors
`md/data`	
`notes`	notes and references
`pi0`	π^0 calibration codes

B Spacal Data Taking and Reconstruction

Primer for Calibrators

Figure 1 shows a sketch of the Spacal data flow. In a) the successive splitting, shaping, measurement and digitization of the PMT pulses is illustrated. The Spacal electronics consists of three branches, an energy, a trigger and a time measurement branch. Time and energy of events triggered on trigger level L1 and accepted by level L2 are measured and digitized using ADC, discriminators and TDC (respectively). More detailed descriptions can be found in [5, 6, 8]. DSP (Digital Signal Processors) are used for zero suppression and the production of raw data banks. The digitized data are then fed into a software filter (L4) where an event reconstruction is performed. For details of the Spacal reconstruction (also on L5) we refer to [22]. The Spacal energies are calibrated using the corrections stored in the SCKP bank. Selection criteria are imposed according to the H1 classification scheme. The events accepted are written onto tape (RawData). In addition a subsample of the selected events is written to separate storage media for monitoring purposes. For the Spacal in particular the LED tapes and the kinematic peak tapes must be mentioned. The event selection criteria are defined in the H1REC-Routines SPFLAG and SPLED, respectively. The final reconstruction of all selected events and the production of POT (Production Output Tapes) and DST (Data Summary Tapes) is performed on the SGI-machine 'dice1' (L5). In contrast to L4 where no LED corrections are applied to the Spacal data, L5 uses the LED data to correct for time dependences. The process to calculate the corrections and fill the database is called SMON. According to the present setting SMON accumulates 200 events for each cell and calculates a mean. For reasons of data compression the result is converted into integer numbers using a stepwith of 0.5%. The database bank SLED is filled only if for a given run at least one cell differs from the previous run[19].

C HV settings 97

Date		Run Period		HV	Method of	Relative
from	to	first run	last run	set	calibration	Gain equal.
04.03.97	11.03.97	178322	178997	260	96 setting	$\sim 3\%$
					Kin. Peak/Cosmics, inner 144	
11.03.97	13.10.97	179559	201519	261	same as 260	$\sim 3\%$
					cells 89, 115, 158 changed	
04.04.97	18.09.97	179559	199829	261	BPLUG: 'High HV'	$\sim 3\%$
18.09.97	13.10.97	199889	201519	261	BPLUG: 'Low HV'	$\sim 3\%$

An overview over the periods of High Voltage settings in 1997. The values the banks and log-files used in 1997 are available in `softw/hvset`. Note that for stability reasons the HV has not been changed after a start-up phase which ended at the 11.03.97. The HV for the BPLUG has been changed once before run 199889.

[19] Note that the statistical accuracy of the mean determination (200 events) and the step width (0.5%) determine the size of the contribution of the LED system to the total energy resolution of the Spacal. In order to facilitate future improvements the number of accumulated events should be increased considerably and the step width should be minimized. The number of events N is related to the precision p via the maximal RMS/Mean value of an LED distribution as: $N = (RMS/Mean/p)^2$. E.g. 2500 events should be taken at a maximum $RMS/Mean$ of $\sim 5\%$ to reach a precision of 0.1%. In addition the sensitivity of the Alarm software should be increased in order to allow immediate action in case of problems.

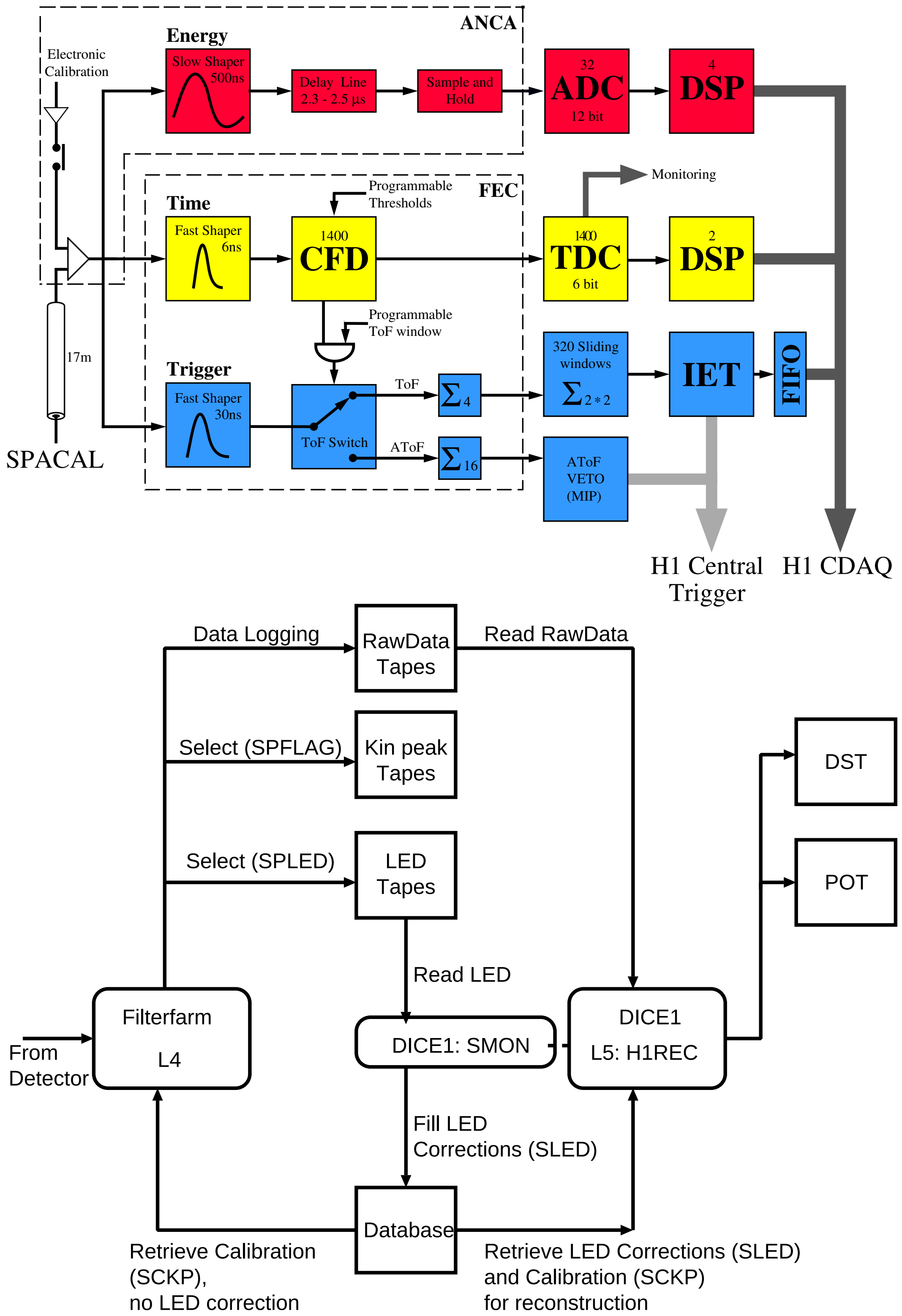

Figure 1: (a) Sketch of Spacal Trigger and Data Acquisition Electronics (Taken from [2, 4]). (b) Sketch of Spacal Data Reconstruction (see text).

D HOW TO: Take Cosmics

Shift Crew

Condition: NO BEAMS in HERA.

Duration: Few Hours (50k evts/h)

Procedure: Move to the System Supervisor:

1. Goto **Readout & Logging** in the General Readout Branch
   - Take only Branch 1 (Central Trigger) and Branch 3 (Calorimeter) into the readout
   - Data Logging Destination: Silicon Graphics
   - Data Logging Mode: Permanent
   - Readout Options: All OFF
   - Filtering & FARM Options: All OFF
   - Goto Overview
2. Goto **Trigger** in the General Readout Branch
   - Click on Test/Calibration (upper red field)
   - Goto Overview
3. Goto **General Trigger Settings** in Detailed Trigger Settings Branch
   - Set all Subtrigger Bits to Zero (Set to \$ 00000000) also in all following Trigger Panels
   - Activate the Subtriggers S118 and S119 and S121
   - Goto Overview
4. Goto **Calorimeter** in Branch Parameters Branch
   - Warmstart Type: Fast Load
   - Calo Data Format: Full Correction
   - Active Detectors: Only SPACAL ON, all others OFF
   - Set SPACAL ZERO SUPPRESSION TO 2.0 (if it is not already done)
   - Lumi run ON, SIET active
5. Goto the H1 System Supervisor
6. Do a WARMSTART from the CDAQ
7. Now you have to load the special IET threshold for the cosmic data taking
   - Goto the FALCO Terminal in the lower level at rack B8 in Room 307
   - select the h1cal10 of the menue (key number 30)
   - login with: cosmic spacal
     The new thresholds were now loaded. During this procedure a slow control power alarm beep in the room 301 will appear (low voltage power alarm). Switch the sound of the alarm off and relax. This is the proof, that the new thresholds were loaded correctly and all you have done up to now is O.K. The alarm will disappear as soon as you will do a warmstart from the CDAQ. But this means also, that the threshold you just loaded will also disappear. So, do NOT do a warmstart from the CDAQ during the whole period of COSMIC data taking. Redo step 7 after each warmstart.

8. Start the run from the CDAQ
9. Now you should see some COSMIC tracks in the SPACAL event display.
10. check the event rate.
    The event rate varies from time to time. The event rates are in the region of 15 Hz to 30 Hz. Usually the subtrigger S119 has a two to three times higher rate than S118.
11. Don't worry when from time to time in the event display the whole SPACAL is full of energy. These events were LED Events to control the photomultiplier gain.
12. After you have written a few 100k events on tape you can stop with taking COSMIC data.
13. Reset all changes at the CDAQ, reboot the h1cal6 and do WARMSTART on the CDAQ (the slow control alarm will disappear after finishing). Do not leave the control room after you set everything back to STANDARD.
14. Report the run numbers of the COSMIC runs to the analyst.

E HOW TO: Take Halo muon Data

Experts Only

Condition: STABLE PROTONS or HERA starts with INJECTION of positrons

Duration: $\sim$ 1/2 Hour

Procedure: Move to the System Supervisor:

1. Goto **Readout & Logging** in the General Readout Branch
   - Take only Branch 1 (Central Trigger) and Branch 3 (Calorimeter) into the readout
   - Data Logging Destination: Silicon Graphics
   - Data Logging Mode: Permanent
   - Readout Options: All OFF
   - Filtering & FARM Options: All OFF
   - Goto Overview
2. Goto **Trigger** in the General Readout Branch
   - Click on PHASE 0 (upper green field)
   - Goto Overview
3. Goto **General Trigger Settings** in Detailed Trigger Settings Branch
   - Set all Subtrigger Bits to Zero (Set to $ 00000000) also in all following Trigger Panels
   - Activate the Subtrigger S20
   - Goto Overview
4. Goto **Calorimeter** in Branch Parameters Branch
   - Warmstart Type: Fast Load
   - Calo Data Format: Full Correction
   - Active Detectors: Only SPACAL ON, all others OFF
   - Set SPACAL ZERO SUPPRESSION TO 2.0 (if it is not already done)
   - Lumi run ON, SIET active
5. Now you have to load the special IET threshold for the halomuon data taking
   - Goto the FALCO Terminal in the lower level at rack B8 in Room 307
   - select the h1cal6 of the menue (key number 26)
   - login with: hera
   - goto the directory 'input' with: cd input
   - edit the file 'acquis.req' with: sedt acquis.req 69 (if you use this 69, you are just in the right line of the file to edit)
   - the cursor should now blink in the line 'run type'. The left number should be now '0'. CHANGE THIS NUMBER TO 2
   - save this file by typing the function 'PF1' AND the letter 'F' together
   - logoff from h1cal6 by typing 'lo'
   - reboot h1cal6 (check before, whether the run is stopped)

6. Goto the H1 System Supervisor
7. Do a WARMSTART from the CDAQ
   The new thresholds were now loaded. During this procedure a slow control power alarm beep in the room 301 will appear (low voltage power alarm). Switch the sound of the alarm off and relax. This is the proof, that the new thresholds were loaded correctly and all you have done up to now is O.K.
   The alarm will disappear as soon as you will change the number '2' in acquis.req on the h1cal6 back to '0' and after again rebooting h1cal6 and a CDAQ WARMSTART.
8. Make sure the proton beam energy is larger than 400 GeV.
9. Start now the run from the CDAQ
10. Now you should see some HALOMUONS in the SPACAL event display (most of the SPACAL should be empty. You should only see a small amount of cells hit in both SPACAL sections).
11. check the event rate
    The event rate varies from time to time. The reason for this is not completely understood up to now. Seen event rates are in the region of 60 Hz to 120 Hz. But the rate should not below 20 Hz.
12. Don't worry when from time to time in the event display the whole SPACAL is full of energy. These events were LED Events to control the photomultiplier gain.
13. After you have written a few 100k events on tape you can stop taking data.
14. Reset all changes at the CDAQ, login again on h1cal6, change directory to 'input', edit the file acquis.req with 'sedt acquis.req 69', replace the '2' with '0' and save the file with 'PF1' AND 'F'. Logout from h1cal6, reboot the h1cal6 and do WARMSTART on the CDAQ (the slow control alarm will disappear after finishing). Set everything back to STANDARD.
15. Report the run numbers of the HALOMUON runs to the analyst.

Remark: Step 5 and step 15 are dangerous and should be avoided by implementing an alternative procedure as soon as possible.

F HOW TO: Take Noise Runs

Shift Crew

Condition: RAMPING of positrons (just after positrons are filled, well before LUMINOSITY is announced)

Duration: $\sim 1/2$ Hour

Procedure: Move to the System Supervisor:

1. Goto **Readout & Logging** in the General Readout Branch
   - Take only Branch 1 (Central Trigger) and Branch 3 (Calorimeter) into the readout
   - Data Logging Destination: Silicon Graphics
   - Data Logging Mode: Permanent
   - Readout Options: All OFF
   - Filtering & FARM Options: All OFF
   - Goto Overview
2. Goto **Trigger** in the General Readout Branch
   - Click on Test/Calibration (upper red field)
   - Goto Overview
3. Goto **General Trigger Settings** in Detailed Trigger Settings Branch
   - Set all Subtrigger Bits to Zero (Set to $ 00000000)
   - Activate the **Random** Trigger
   - Goto **Next Trigger Panel**
   - Set all Subtrigger Bits to Zero (Set to $ 00000000)
   - Do this for all following Trigger Panels
   - Goto Overview
4. Goto **Calorimeter** in Branch Parameters Branch
   - Warmstart Type: Fast Load
   - Calo Data Format: Full Correction
   - Active Detectors: Only SPACAL ON, all others OFF
   - Set SPACAL ZERO SUPPRESSION TO 0.0
   - Lumi run ON, SIET active
5. Goto the Central Trigger Monitor
   - Click on SHIFTS (green colour) on the top bar
   - Activate Branch: Set Random Trigger Rates
   - Put Random Trigger Rate to Maximum
6. Goto the H1 System Supervisor
7. WARMSTART from the CDAQ
8. START the Run
9. STOP the Run after 10000 Events
10. Reset all changes, and do not leave the control room after you set everything back to STANDARD
11. Report the run number of this Noise Run to the analyst and the Spacal coordinator.

G HOW TO: Perform a DSP Calibration

Experts Only

Condition: Between two luminosity fills

Duration: $\sim 1/2$ h

Procedure: Ask the shift crew to stop the run and take the Spacal out of the Central Read Out.

1. Go to the roof of the trailer.
2. Switch the uppermost switch in the VIC (in the OS/9 crate) such that the LED VBRONL goes off.
3. Start SPIDER on OS/9 `h1cal10` (in `daqbis/input`):
   - `test menus`
   - `m` (All Spacal)
   - `p` (Pedestal and Noise Measurement)
   - `Calib Off`
4. NIM Crate K1: Switch the corresponding TRIGGER SELECTION (2th white switch from the top) to 'on' and switch ORSAY CALIBRATION (6th white switch from the top) to 'off'.
5. Run SPIDER:
   - `R` (Reset Database)
   - `S` (Start Pedestal Run)
   - Wait until Run end
   - `A` (storage in database file)
   - `P` (Produce DSP Table)
     The file produced is called `pedes.dba` in directory
   - Press `print out` key. Store print out in folder.
6. After running SPIDER on OS/9 `h1cal10` Account: `daqbis`
   - Store print out in folder.
   - Copy `dspc_sp.cal` to `dspc_sp.cal.'date'`.
   - Ftp the file from the OS/9 to dice of AFS. Use `~~boudry/spacal/pedes/noise.kumac` in PAW: Type `exec noise#read pedes.dba`
   - Ftp `dspc_sp.cal.'date'` to `h1cal6`. Type `bin` (for binary transfer).
7. On OS/9 `h1cal6` Account: `hera/calib`
   - Check if the file `dspc_sp.cal` has already been archived: `cmp dspc_sp.cal dspc_sp.cal.'date'`. The files should be different.
   - Copy new `dspc_sp.cal.'date'` to active file `dspc_sp.cal` `copy -r dspc_sp.cal.'date' dspc_sp.cal`

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