The Performance of the H1 Liquid Argon Calorimeter

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- Introduction
- Cryogenic System
- Purity Determination
- Stability of Electronics
- Trigger and DAQ
- Noise Filter and HV Corrections
- Calibration and Final Energy Scale
- Preamplifier Upgrade
The H1 Liquid Argon Cryostat

- LN₂ for Cooling
- Ht Forward Cable Feed Throughs
- HV Feed Thru
- SC Coil Cryostat
- Base Structure of Iron Yoke
- N0 Rear Signal Cable Feed Throughs
Longitudinal Cross Section
of the H1 Liquid Argon Calorimeter

8 wheels, built out of 8 octants in each section

8m. section: 30784 cells
had. section: 13568 cells

total 44352 cells
but 60470 channels due to 2 gains for ≈ 16000 cells

10 to 100 cm²
50 to 2000 cm²

20 - 30 X₀
4.7 - 7 λ

4° ≤ θ ≤ 154°
Performance of the Cryogenic System

The Cryogenic System

- is steered by a set of VME based OS9 systems and monitored every 30 seconds via a PC based system

- Cryogenic data – averaged over 1 hour – are stored in an ORACLE database
  → small data volume: 2 MB/year
  → very good tool for systematic studies
  → easy access (e.g. via WWW, for H1 members only)

- stable conditions during the data taking period:
  Pressure (PT710): 1.28 bar
  Temperature (TT720): 88.8 K

- some micro structures visible, e.g. refill of LN₂

- stable in operation since 1991, no warm-up since the cryostat was filled

- since 94 the cryostat is even not emptied, the LAr stays during movements of the detector
Cryogenic Data on WWW

Netscape: Oracle Query for the Cryogenic data, Results

Location: http://www-h1.desy.de/igci-calo/cryo.pl

Cryogenic data between 1.1.1996 00:00 and 1.1.1997 00:00

Levels

Level

Diff. pressure

Temp.
Performance of the Cryogenic System in 96 and 97: Pressure and Temperature

(During periods of data taking)

**Pressure PT710**
- Entries: 9248
- Mean: 1.278
- RMS: 0.166E-02

**Temperature Probe TT720**
- Entries: 9248
- Mean: 88.81
- RMS: 0.5439E-01

**Temperature Probe TT730**
- Entries: 9248
- Mean: 88.49
- RMS: 0.3638E-01
Performance of the Cryogenic System: Structures during refill of N2
Purity Measurements

To monitor the LAr purity H1 uses:
- Cosmic or Beam Halo Muons:
  performing an HV curve (about twice a year)
- 11 probes:
  Ionisation chambers, installed at different place in the calorimeter, equipped with an $\alpha$ or $\beta$ source
  (HV is supplied independently of the Calorimeter HV)

Two ways of operation:
- a) recording the spectrum (every 2 hours)
- b) performing an HV curve (once every 2 months)
Purity Determination using Cosmic or Halo Muons

- take an HV curve (250-500-750-1000-1250-1500V)
- read out all cells of the LAr without zero suppression
- isolate the track (using tracker and muon system) and optimize a cylinder around the track
- perform a noise/pedestal analysis
- use the parametrization of track like charges for the fit and determine the charge collection efficiency:

![Graphs showing charge collection efficiency](image)
Purity Monitoring using $\alpha$ and $\beta$ Probes

- record the $\alpha$ and $\beta$ spectra (automated task, every 2 hours)
- correct for various side effects (e.g., temperature of the LAr)
- follow the slope of the peak positions (allows to detect leakages on a short time scale)
- no absolute measurement, only relative measurement, but fast detection/reaction possible in case of problems

Probe 10: 0.3%/year (corrected for geometry)
Purity Determination via Probes using an HV Curve

- Determination of peak positions at various HVs (automized task running on the purity PC)
- Perform a fit (pointlike charge!)
The Electronic System

- Preamplifiers are mounted **outside the cryostat**

2 independent pulser systems:

"Cold calibration": Signals are fed in close to the pads
"Warm calibration": Signals are fed in close to the PAs

- Easy access to frontend electronics
  → **excellent channel statistics**, e.g. in 97:
  111 dead channels from 60470 electronic channels (0.18 %)
  67 of these 111 channels are weak due to magnetic field
  19 of these 111 channels known to be problematic since 91
  typically 10 – 30 new problematic channels per year
  (which are repaired during regular shut downs)
The Electronic System:
Stability in 97

Comparison of the performance: (Mar 97 – Oct 97) / Oct 97

raw data / unciliated

RMS: 0.7%  
Entries: 63488  
Mean: -0.1024E-03  
RMS: 0.6917E-03  
UDFLW: 67.00  
OVFLW: 3.000

RMS: 4%  
Entries: 63488  
Mean: -0.7644E-02  
RMS: 0.4002E-01  
UDFLW: 133.0  
OVFLW: 103.0

RMS: 1.8%  
Entries: 63488  
Mean: -0.6463E-03  
RMS: 0.1794E-02  
UDFLW: 792.0  
OVFLW: 290.0

Stability of Charge at doc = 9600
The Electronic System:
Noise Search and Noise Reduction

Detected noise sources:
- Oxygenmeter of the cryogenic system
  (detected by pattern: 12 sec noise, 18 sec pause)
- Cryo power supply
  (40 kHz noise, DC coupler replaced)
- Main power supply of the solenoid
  (thyristors adjusted to a new working point)
- Temperature probes
  (lines decoupled)
- Power supply of the toroid magnet
  (similar to the solenoid problem, capacities added)
- Ground lines between ANRU and ANBX
  (ground lines were disconnected)
- ICs inside ANRUs (two "identical" chips of different producers reordered)
- . . . .
- low/white noise reached in most regions of the calorimeter
The Electronic System:

Noise in 97

Noise in

CBE: $\approx 30$ MeV (0.25 mips)
CBH: $\approx 30$ MeV (0.15 mips)
IFE: $\approx 15$ MeV (0.15 mips)
IFH: $\approx 24$ MeV (0.15 mips)
The H1 LAr Trigger System

Outline of the LAr big towers

Date 2/02/1995

bigg objects: $E_{\text{trans}}$, $E_{\text{t,miss}}$, ...

trigger cell

big tower

big tower

Layout of the LAr Trigger

trigger elements

electron 1,2

E-tot

E-tot,miss

E-trig

E-weight

sum over all BTs

coincident BT

several summing steps
Trigger Calibration

![Graphs showing various data distributions related to trigger calibration.](image)

- **Offset (GeV/8)**
  - Mean: 0.40275±0.1,
  - RMS: 0.236

- **Slope (GeV/8 counts)**
  - Mean: 1.054,
  - RMS: 0.0784±0.01

- **E_{FADC} (counts)**
  - Plot showing a linear relationship with a slope indicating

  \[ \text{E}_{\text{FADC}} \text{ count} = 125 \text{ MeV} \]
Noise Behaviour in the Trigger Branch

\[ \sigma_{\text{trig}} = \sigma_{\text{calo}} \sqrt{\frac{T_{\text{calo}}}{T_{\text{trig}}}} \]

- Trigger
- Analog "Calo"

- e\text{m} trigger towers
- had trigger towers

\[ A_{\text{FADC count}} = 125 \text{ MeV} \]
The Performance of the DAQ

- 44532 calorimeter cells
- 60470 electronic channels
- Zero suppression applied:
  - Central Barrel: $2.0 \times \sigma_{\text{noise}}$
  - Forward Barrel: $2.5 \times \sigma_{\text{noise}}$
  - Inner/Outer FCAL: $3.0 \times \sigma_{\text{noise}}$
- Channels passing the zero suppression, based on 3000 randomly triggered events

Average time needed for the calorimeter readout: 1.1 msec
(incl. channel wise third order corrections in the DSPs)
The Offline Noise Filter

Offline reconstruction uses a noise filter:

- Based on 3000 randomly triggered events (0.2 Hz Rate)
- Update of noise filter approx. every 5 hours
- About 80 channels ($\approx 0.13\%$) are suppressed:
  - **HOT** channels, if: $|Q| > 4\sigma_{noise}$ 35%
  - **NOISY** channels, if: $\sigma_{noise} > \sigma_{max.wheel}$ < 5%
  - **BIG** $Q_{mean}$ channels, if: $|Q_{mean}| > 5\sigma_{noise}$ 60%

![Graph showing channel counts over runs with a note on luminosity period 97]
The HV system

- ≈ 8000 gaps
- 1504 HV lines connected to 56 distributors with 32 channels → In average 5 planes are supplied by a common HV line

- Electric field: 625 V/mm, guarantees smooth operation
  92.8 % of all HV lines on nominal voltage (1500 V)
  3.5 % on nominal voltage, high currents (up to a few µA)
  3.5 % on reduced voltage (1000 V)
  0.2 % grounded
- Very stable HV (now, but not in the first years)
- Very sensitive to bad beam conditions
- Trips occur mostly during bad proton injections
HV Corrections

- Status of the HV situation is regularly recorded
- Significant changes are recorded via the slow control system ("slow events")
- Typically 500 "slow events" per day
  (100000 per year ≈ 1 Mbyte)
- Stored in ORACLE database, available for the reconstruction
- Typical correction factors applied on cell energies:

  ![Histogram](image)

- About 8600 of 44532 channels/cells are getting HV corrections of about 2% in average
HV Corrections:
Improvements of the Energy Scale

- Local inhomogeneities are cured:

- Energy scale improved:
HV Corrections:
Improvements of the Energy Scale

- Local inhomogeneities are cured:

- Energy scale improved:
Calibration

Linearity: ± 1% up to 166 GeV

Resolution: \( \frac{dE_e}{E_e} = 12\% / \sqrt{E_e (GeV)} \pm 1\% \)

Systematic Uncertainty on the Energy Scale:

Electrons: 3 %

Hadrons: 4 %

(verified by ep data collected between 93 - 94)

Hadrons in the test beam:

\[ \frac{dE_h}{E_h} = 50\% / \sqrt{E_h (GeV)} \pm 2\% \]
Calibration Methods with $ep$-Physics

- Electromagnetic energy scale
  - $\pi^0$ signal
    - Used for systematic tests
    - $E_\gamma \approx \text{few GeV}$

- QED-Compton events
  - Wide angle bremsstrahlung
  - $\Rightarrow$ $e^-\gamma$ System balanced
  - But: Very small cross section, low statistics
  - $\Rightarrow$ Check of linearity

- High $Q^2$ events
  - Angles and energies are constrained
  - $P_{te}$ and $P_{eh}$ balanced
The Double Angle Method

- The Electron Energy can be determined using:
  the angle of the scattered electron $\theta_e$
  the angle of the struck quark jet $\gamma$

- $E(\theta_e, \gamma) = \frac{2 E_{e,beam} \sin \gamma}{\sin \gamma + \sin \theta_e - \sin(\gamma + \theta_e)}$

- Select good electron candidates:
  $E > 11$ GeV, $z > -180$ cm, $E - p_z > 35$ GeV

- Calibrate the electromagnetic energy scale in $z$ direction

- Calibrate the individual octants

- Correct/test the hadronic energy scale using the knowledge of the calibrated electromagnetic energy scale

- Statistics available: 85000 events based on 32 pb$^{-1}$
High-$Q^2$ Data:
Calibration of CBE in Bins of $z$
Using the Double Angle Method

$z = -200 \text{ cm} \ldots \ldots -175 \text{ cm}$

$z = -175 \text{ cm} \ldots \ldots -150 \text{ cm}$

$z = -150 \text{ cm} \ldots \ldots -125 \text{ cm}$

$z = -125 \text{ cm} \ldots \ldots -100 \text{ cm}$

$z = -100 \text{ cm} \ldots \ldots -75 \text{ cm}$

$z = -75 \text{ cm} \ldots \ldots -50 \text{ cm}$

$z = -50 \text{ cm} \ldots \ldots -25 \text{ cm}$

$z = -25 \text{ cm} \ldots \ldots 0 \text{ cm}$
High-$Q^2$ Data:
Before and After Calibration

- H1 1994–96

- H1 1994–96 cor.
High-$Q^2$ Events:

$z$-Dependence of the Calibration in Data (●) and MC (○)
High-$Q^2$ Events:
$\phi$-Homogeneity after final Calibration
High-$Q^2$ Data:
Distributions after Calibration in Data and MC

Scattered electron energy tails due to physics!!
High-$Q^2$ Events:
Stability of the Calibration

- 95 data
- 96 data
- 97 data

Graphs showing distributions of variables such as $E$, $E_{\text{DA}}$, $p_T$, and $E-P_z$.
Jets in High-$Q^2$ Events: $p_{t,\text{had}}/p_{t,\text{el}}$

Agreement between Data and MC

The H1 LAr Calorimeter is of non-compensating type. $ightarrow$ hadrons are reconstructed using S/W weighting techniques.
The next step:
Upgrade of the Preamplifiers

Old JFET:
SK372 (Toshiba) 60 mSi

New JFET:
NJ3600 (Interfet) 200 mSi

\[ \sigma^2 = 2kT \cdot \frac{C_{im}}{g_m} \left( \sqrt{\frac{C_{et}}{C_{im}}} + \sqrt{\frac{C_{im}}{C_{et}}} \right) \]
The next step:
Upgrade of the Preamplifiers
Benefits of the Preamplifier Upgrade

- Better resolution: G/E
- Lower thresholds @ same rate
- Significant lower rate @ same thresholds
Summary and Outlook

- The H1 Liquid Argon Calorimeter has a good performance w.r.t. cryogenics and stability of purity.
- The stability of electronics and HV is excellent, ensuring smooth trigger and DAQ operation.
- The MC is able to describe the detector response very well in many details.
- Recent analyses of electrons above 20 GeV show the potential to improve the precision of the energy scale to a level of 1%.
- Hadronic measurements are well under control and an error of 3% seems achievable for the hadronic energy scale.
- With the preamplifier upgrade we will
  - reach lower energies in the analog readout
  - apply lower trigger thresholds
  - have a smooth performance, even under high luminosity conditions.
- This good performance was achieved thanks to
  - a well designed calorimeter system
  - a carefull operation and monitoring of the various calorimeter subsystems
  - and an intensive analysis work.