Calorimetry and the DØ Experiment

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Stony Brook and LAPP
CALOR 2004
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Calorimeter Description
Liquid Argon Calorimeter

- 3 cryostats: central (CC) + 2 end caps (EC)
- 3 sections: EM + HAD + CH
- Plate geometry
  2.3 mm LAr gaps + 4.6 mm G10 electrodes
- 1.6 kV; ~ 450 ns drift time
- Coverage: $|\eta|<4.2$
- Granularity: $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$
  0.05 \times 0.05 at shower max

<table>
<thead>
<tr>
<th># of $X_0/\lambda_0$</th>
<th>Absorber</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC EM</td>
<td>2 + 2 + 7 + 10</td>
</tr>
<tr>
<td>CC FH</td>
<td>1.3 + 1 + 0.9</td>
</tr>
<tr>
<td>CC CH</td>
<td>3</td>
</tr>
<tr>
<td>EC EM</td>
<td>0.3 + 3 + 8 + 9</td>
</tr>
<tr>
<td>EC FH</td>
<td>1.3 + 1.2 + 1.2 + 1.2</td>
</tr>
<tr>
<td>EC CH</td>
<td>3 + 3 + 3</td>
</tr>
</tbody>
</table>
Results from Run I – Upgrade for Run II

• Run I: very successful operation
  • Energy resolution (W mass paper)
  • $e$: central $\sigma_E / E = 13\% /\sqrt{E} + 1.5\% + 0.4 \text{ GeV}/E$
  • end caps $\sigma_E / E = 16\% /\sqrt{E}$
  • had: $\sigma_E / E = 80\% /\sqrt{E} + 4\% + 1.5 \text{ GeV}/E$
  • Less than 50 dead channels out of 55000

• Run II upgrade: 3.5 $\mu$s between crossings? 396 ns
  • Replace front end electronics and cables
  • Keep cabling, crates (power supplies) and ADC cards
  • Replace calibration system, timing and control system
Electronics Description
Basics of Readout

- Detector signal ~ 450 ns long
- Charge preamplifiers
- BLS boards
  - Short shaping ~2/3 of signal integrated
  - Signal sampled and stored every 132 ns in analog buffers waiting for L1
  - Samples retrieved on L1 accept and baseline subtraction (BLS) to remove pile up and low frequency noise
  - Signal retrieved after L2
  - Digitized
Preamplifiers

• Charge preamplifier similar to Run I

• Hybrid on ceramic
• Dual front end FET (noise/v2)
• Compensation for detector capacitance
  • 0.25 – 4 nF ? 14 different species

• up to 48 channels per board
• i.e. 4 towers (Δη × Δφ = 0.2 × 0.2)
• 1152 boards

• Very reliable system (inside iron, ~ 1 day access time!)
BLS Boards

• 48 channels from $\Delta \eta \times \Delta \phi = 0.2 \times 0.2$
i.e. 1 trigger tower
  • Trigger summers + drivers
  • Shapers
  • L1 and L2 analog memories (SCA)
  • Baseline subtraction

• 4 daughter cards ($\Delta \eta \times \Delta \phi = 0.1 \times 0.1$)
  • 2 gains $\times 8$ and $\times 1$ (12–bit ADC, 15–bit dynamic range)
  • Analog memories not simultaneously read–write

• In the collision hall, short access time (~ 1 hour)
SCAs

- Designed by LNBL, FNAL, SUNY Stony Brook
- 12 channels × 48 cells deep memories
- Allow ~ 6 µs for L1 decision time (4.2 µs)
- Read time 2.5 µs
- No dead time @ 10 kHz L1 trigger rate

On–board properties
- pedestal dispersion 0.6 ADC count rms; acts as coherent noise
- non linearity at low ADC values (software corrected)

2.5 cm
12 channels
48 deep

a really bad one!

ADC vs DAC 2004

Gain x1

20 ADC counts

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ADC Cards

- 144 ADC cards (12 crates x 12 cards) from Run I
- Each card houses 24 successive approximation digitizers (2.5 μs)
- Each digitizer services 16 sequential frames
- pedestal subtraction (optional)
- settable zero suppression? only ~ 5000 cells read out @ 1.5 σ

Timing and Control Cards

- Receives accelerator, clock and trigger signals
- Distributes those to BLS and ADC boards
- Keeps track of where relevant data are sitting in SCAs
- Generates busy signals
- Driven by code in FPGAs
Pedestals – Noise
Noise

- Electronics contribution (except preAmps) < 1 ADC count

- Noise increases with capacitance

- Uranium noise (HV on/off)
  - sensitive only for large area channels (high capacitance)
  - Gaussian!
Coherent Noise

• from SCAs below 1 ADC count

• DØ had to be grounded for safety reasons
  • designed to have a single point grounding
  • was OK for Run I and then forgotten by many of the community
  • and some day, …

• Dozen of contacts of DØ and with “ground”

• Ground repaired + some temperature monitoring cables disconnected

• Gone (for ever?)
Pedestal Stability

• Pedestal run taken in between stores (every ~ 30 hours)
• Mean values and rms computed in L3 filters (data not written to tape)
• $10^4$ events @ 20 Hz, altogether ~ 15’

• Excellent long term stability
• Tool able to find channels drifting by <1 ADC count/month

• No pedestal shift in physics
  No change in noise
Calibration
Pulser System

- Similar to ATLAS system
  - 1 mH inductance loaded by a DC current
  - opening a switch diverts current to ground
  - inductance produces exponential calibration current through precision injection resistors
  - but charge injected at preamp input

- 12 pulsers
  - 6×16 DC currents; a single 18-bit DAC controls intensities ($\propto$ pulse height); individually enable; better than 0.2% linearity
  - 6 command lines each with a programmable 8-bit delay (0–400 ns) ($\propto$ pulse start)

- 12×6×16 switches close to preamplifiers
Calibration Pulses

- Measured by varying the delay

- Reflection on detector capacitance due to injection close to preAmps
  - most pronounced for high capacitance cells (HAD)
  - still visible in EM channels

- Needs to be taken into account
Reflection Measurements

• Using a Time Domain Reflectometer
  • send a square pulse
  • measure reflected signal
  • complicated fit yields
    • detector capacitance
    • strip capacitance and inductance
    • various cable lengths
    • skin effect parameter

• 55,000 channels measured and parameters extracted
Electronics Simulation

- Individual channel properties before preAmp known
- Cables, detector capacitance, etc. known
  
  ? Predicted input pulse to preamps

- Generic description of each preamp type
- Generic description of one shaper

\[\text{red line = preAmp input} \quad \text{black line = shaper output}\]
Plans for Full Calibration

- In calibration mode, from
  - predicted input signal to preamp (channel per channel)
  - measured output signal from BLS

  ? compute numerically transfer function H (preamp + shaper)

- In physics mode, from
  - predicted physics input signal to preamp
  - transfer function H

  ? predict channel to channel variation in pulse height

- Calibration = correction for those variations

- Long way to go!
Other Pieces
Inter Cryostat Region

- Limited coverage of region $1.1 < |\eta| < 1.4$
- ICD detector similar to Run I
  - Scintillator + WLS fiber + clear fibers
  - Reuse of R647 Hamamatsu PMT’s (low B)
  - 2×16 modules (384 channels)
  - Electronics adapted from calorimeter
  - Same RO
  - Same electronics calibration system as calorimeter
  - PMT calibration with cosmics on test stand + LED pulsers for monitoring

- Massless gaps in CC and EC
Preshower

- 2 teslas Solenoid in Run II (60 cm radius)
- Energy loss backed by a 2 $X_0$ preshower
- Scintillating fibers + lead
- WLS readout + ~10 m clear fibers
- VLPCs + 8-bit ADC
- Central ($|\eta|<1.3$, CPS)
  - 7680 channels
  - 3 layers (axial, u, v)
- End caps ($1.5<|\eta|<2.5$, FPS)
  - 4 layers (u, v) + lead
  - 15000 channels
- Effort yet concentrated on track matching and $\gamma/\pi^0$ rejection
Trigger

- Granularity $0.2 \times 0.2$ down to $|\eta| = 3.2$
- Analog signal pickup in BLS boards
- Sums of em and had sections separately
- Converted to $E_T$
- Flash digitized @132 ns; 8 bit precision.
- Pedestal and gain compensation
- Excellent comparison with “precision” readout
  - Alternative route to check data
Some Results
EM Performance

• Benchmark is Z peak. Also J/Ψ and Y available to compute in beam resolution (see Sophie Trincaz – Duvois’s talk)

• High mass pairs

![Z mass peak graph](image)

![DiEM Mass Spectrum](image)
MET

• Missing $E_T$ quality very sensitive to any calorimeter problem ("hot cells")
• Resolution dominated by jet resolution
• Bench mark: W mass ?
• Underlying event ?

$E_T$ Distribution of Electrons

Transverse Mass

$\mathcal{L} = 42 \text{ pb}^{-1}$
Jets

- Resolution measured from $\gamma/\pi^0$–jet events (see Sacha Kupco’s talk)
- Response uniformity
Summary

- Mechanical design and building of 1980’s

- But almost entirely new electronics build for high luminosity
  - no test beam debugging

- Commissioning not ended by the time good beam was delivered
  - no long time of cosmic run debugging as in Run I

- Debugging with beam is very difficult!

- Still many detector studies in progress to get ultimate information out of the data

- Data quality (see next talk, Slava Shary, LAL, Orsay)