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The ATLAS Liquid Argon Calorimeter at the LHC

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Outline

- Introduction
 - the LAr Calorimeter of the ATLAS detector
- **Electronic calibration**
 - energy reconstruction
- **Results with cosmic muons**
 - signal shape
 - uniformity of response
- **Results with single beam and splash events**
 - timing
- **First collisions!**
- Conclusions

The ATLAS experiment

- 1992 Letter of Intention
- 1997 start of construction
- until 2004: test beam
- 2008: installed in the tunnel
- until today: cosmic runs
- fall 2008 and 2009
 - ✓ beam in LHC
 - ✓ splash events
- 23/11/09 first collision at 900 GeV
- 08/12/09 first collision at 2.36 TeV

Physics analysis:

Higgs : $H \rightarrow \gamma\gamma$, $H \rightarrow 4l$

SUSY (+exotics): missing E_T

SM signatures : Z and W
(leptons and missing E_T)

Hadronic environment:

p-p collisions every 25 ns, nominal E of 14 TeV

➤ high interaction rates and high radiation

Requires very good calorimetry!

- energy resolution
- coverage in η and ϕ
- missing E_T reconstruction
- accurate time measurement
(eventual new, long-lived particles)

The ATLAS LAr Calorimeter

Electromagnetic calorimeter Pb+LAr

Complete ϕ coverage
Pseudo-rapidity $|\eta| < 3.2$

3 longitudinal layers

strips: $4.3 X_0$
($\Delta\eta \times \Delta\phi = 0.003 \times 0.1$) $\eta = 0$

middle: $16 X_0$
back: $2 X_0$

+presampler
at $|\eta| < 1.8$

LAr hadronic
end-cap (HEC)

LAr electromagnetic
end-cap (EMEC)

LAr electromagnetic
barrel

LAr forward (FCal)

Energy resolution:

$$\frac{\Delta E}{E} = \frac{10\%}{\sqrt{E(\text{GeV})}} \oplus 0.7\%$$

The ATLAS LAr Calorimeter

Hadronic endcap Cu+LAr (4 layers)

Coverage $1.5 < |\eta| < 3.2$

Energy resolution

$$\frac{\Delta E}{E} = \frac{50\%}{\sqrt{E(\text{GeV})}} \oplus 3\%$$

Forward calorimeter:
Cu(em-1 layer)/W(had-2 layers)+LAr

Coverage $3.1 < |\eta| < 4.9$

Hadronic energy resolution

$$\frac{\Delta E}{E} = \frac{100\%}{\sqrt{E(\text{GeV})}} \oplus 10\%$$

in total: 182468 LAr channels
common readout system
✓ 98.7 % are used
✓ 94 % with nominal HV

Ionization and calibration signal

Ionization and calibration signal

For calibration runs:

a known exponential current is injected and then amplified, shaped and read

Ionization and calibration pulses don't have the same shape

Energy reconstruction

Regular electronic calibration runs (in every fill in when running)

- pedestal and noise measurement
- delay runs for the detailed pulse shape
- ramp runs to measure the gain (ADC to DAC)

Electronic calibration

low and very stable noise

- The calibration constants are stored in a data base and used for the energy reconstruction
- They are updated in every calibration run if needed

Stability of the calibration constants

Cosmic data taking

Cosmic muons

September-October 2008
June-July 2009

300 million events recorded

Study of the signal shape

Signal of cosmic muons:

shape very well predicted by the
electronic calibration procedure
(residuals < 2%)

Drift time extraction

depend on HV and gap size

electromagnetic barrel (constant)

➤ gap size variations (constant HV)

drift time uniformity: 1.27 %

contribution to E ct term: 0.29 %

endcaps: varying gap size

Uniformity with cosmic muons

Projective muons
leave a very clear
signal in the LAr

➤ study of the uniformity: at 1% level

LHC single beam

beam

closed collimator

splash events using the
September 2008 and
November 2009
single beam data taking

LAr Timing

Relative time per Front End Board
~1 ns accuracy for every sub detector

First observed collision

ATLAS
EXPERIMENT

2009-11-23, 14:22 CET
Run 140541, Event 171897

Candidate
Collision Event

Collision event with 2 jets

Collision Event with 2 Jets

Energy in the LAr cells

Collision energy in the LAr wrt
random trigger energy

Good data-MC agreement

average E_T value all over the LAr
calorimeter in collisions
cluster seeded by cells with $E > 4\sigma$

Missing E_T reconstruction

- Use of the complete calorimeter coverage ($|\eta| < 4.9$)
- Take into account only cells in clusters (noise suppression)

For the moment: (next steps)

- no dedicated calibration for different final state objects (electron/photon/jet)
- no specific hadronic calibration

Good agreement
between data and MC

Level 1 calorimeter trigger

- **LVL 1 calorimeter trigger**
- energy sum of cells belonging to a trigger tower reconstructed online
- tower size: $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$

- Correlation with the offline reconstructed energy in 0.1×0.1

- $E_T(L1)$ resolution $< 5\%$ for $E > 10$ GeV

π^0 observation

π^0 selection:

- E_T (cluster) > 300 MeV
- E_T (π^0 candidates) > 900 MeV
- shower shape cut

Conclusion

- The ATLAS LAr Calorimeter is completely installed since 2008
- Commissioning and calibration campaigns have been continuous
- It has been studied and tested using
 - test beam (until 2005)
 - cosmics (since 2008)
 - splash events (fall 2008 and 2009)
 - collisions (since November 2009)
- The LAr performance is excellent and very close to expected

Ready for the coming longer data taking !