Test beam data analysis for the CMS CASTOR calorimeter at the LHC

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The CMS experiment at the LHC

- CMS $\Rightarrow$ Compact Muon Solenoid
- onion shell structure
- length: 21 m
- radius: 7.5 m
- weight: 12500 t
- high magnetic field (4 T solenoid)

Figure: Slice of the CMS experiment
The CASTOR forward calorimeter

CASTOR ≜ "Centauro And STrange Object Reasearch"

- detector based on the Cherenkov effect
- used for pp and heavy ion collisions (Pb-Pb)
- $\eta$ coverage: $5.2 < |\eta| < 6.6$
- installed 14.4 m from CMS interaction point
Why do we need CASTOR?

We need it...

- to measure the PDFs at low momentum fractions $x$
- to improve the understanding of the strong interaction
- to support the Higgs measurements (higher acceptance of the CMS detector)
- to watch the shower development and investigate the nature of exotic objects like "Centauros"
- and many further applications

Centauros are rare cosmic events with a very high hadronic fraction.
What is CASTOR made of?

- sampling calorimeter:
  - active material: quartz plates (Q)
  - absorber material: tungsten plates (W)

- 16 semi-octants around the beam pipe

- each semi-octant:
  - 2 em and 12 hadronic channels (Readout Units (RU))

- each RU has several Sampling Units (SU)

- SUs are made out of Q and W plates
The CASTOR forward calorimeter

How can we measure the particles with CASTOR?

- relativistic particles hit the detector
- they cause a cone of light (due to the Cherenkov effect)
- light is collected and transported via light guides
- the signal is amplified with photomultipliers
The CASTOR forward calorimeter prototype
The CASTOR forward calorimeter prototype
The test beam setup

- protons are accelerated with the SPS
- protons hit a target $\Rightarrow$ secondary particles
- magnets and collimators select particle mass and energy
- readout is triggered by coincidence of signals from scintillators
- wire chambers measure position of beam particles
- large scintillator behind CASTOR can veto muon particles
The test beam setup II

- prototype for the test beam consists of two semi octants
- semi octants are called "Saleve" and "Jura"
- particles enter the detector on Saleve side
Beam profile

CASTOR face (projected) with hits: Run 48654

- Entries: 44298
- Mean x: 20.51
- Mean y: 69.51
- RMS x: 6.443
- RMS y: 6.403

The test beam setup
Pedestal analysis

Pedestal amplitudes

- electronic noise: each signal as a certain offset $\Rightarrow$ Pedestal
- get the "real signal": subtract this offset
- check first: Is the pedestal stable in each channel?
  $\Rightarrow$ Plot the mean pedestal of one channel for each electron run.
Pedestal analysis

Pedestal amplitudes

- pedestal → offset
- width of pedestal: noise of electronics
- amplitudes are shown in the histogram

Figure: Pedestal pulse shape
Pedestal mean stability

- errors of means are very small
- mean of the pedestal is stable
Pedestal RMS stability

- RMS values are stable as well
- electronics is ok
Further cross checks

- Electron energy scans: Check if the beam changes its profile
  - require a single wire chamber hits in x and y direction
  - calculate difference between the position of different wire chambers

- Scintillator counters checked: worked as expected

- Check the stability of the LED runs
The electron scans

Difference of wire chamber C and E
The electron scans

Difference of wire chamber E and B
The LED runs

The LED run

Figure: LED pulse
The LED runs

The LED run

Figure: LED amplitudes
The LED runs

LED runs: mean value and rms

**Figure:** Mean stability of LEDs

**Figure:** RMS stability of LEDs
Intercalibration factors

- each channel has another response to particles with the same energy
  ⇒ We have to find the relation between the channels.

- Muons can fly through all channels without being absorbed.
  ⇒ Use muons with a certain energy to gauge the channels.
Intercalibration with muons

- fit function: sum of three Gaussians
- fit the pedestal peak first
- fix mean and rms of the pedestal peak
- fit distribution

Figure: Channel 0 (em)
How do we get the signal?

- signal for each channel: sum of time bins 3-6 without pedestal
- in this run: electrons are used
  ⇒ we expect most of the signal in the two em channels and the first hadronic channel (ch 0-2)
- sum of channel 0-2 while using the intercalibration factors
Signal without cuts

Require only beam trigger and single hit in wire chamber E

Figure: Electrons with E = 180 GeV
Comparison of different cuts

Figure: Result of different cuts
Resulting signal after cuts

- **hadron cut**
- **muon cut**
- **beam cut:** accept only events which hit the wire chambers in a circle of 2 mm around the beam center

**Figure:** Result after 3 different cuts
Linearity and Resolution

Linearity of detector response

Figure: Linearity
Resolution of the detector

**Figure:** Resolution

\[ \chi^2 / \text{ndf} = 18.28 / 5 \]

\[ \alpha = 0.01305 \pm 0.001208 \]

\[ \beta = 0.3599 \pm 0.01334 \]
### Conclusion

- Pedestal mean and RMS are stable and can be used
- Long term stability of the LED amplitude at a level of 10%
- LED intensity should be decreased for other studies
- Linearity of the detector is not satisfactory (beam stability)
- Resolution as expected

### Outlook

- One has to check the sensitivity of the intercalibration factors
- Further studies of the linearity are necessary
Conclusion and outlook

**Conclusion**

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