# Shower Production by Highly Energetic Muons

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In the barrel region of the ATLAS detector, monitored drift tubes (MDT) will be the sensitive components of the muon spectrometer. LMU and MPI Munich will build and put into operation 90 MDT chambers with 3,78 m long drift tubes for the outer barrel region of the ATLAS detector, so-called BOS chambers [1]. A BOS chamber consists of two triple layers of MDT's. A prototype BOS chamber was built and successfully tested at the H8 muon beam at CERN in summer 1998.

In addition to the tests regarding the mechanical and operational functionality of the prototype chamber, the shower production by high-energy muons was tested by directing the muon beam through a 5 cm thick iron absorber. Multiplicity distribution at high energies have not yet been tested with high precision sprectrometers. The analysis of the data showed a discrepancy between a GEANT 3.21 simulation and the test-beam measurement which, in part, could be attributed to the experimental set-up [2]. Therefore the measurements were repeated with an improved set-up in 1999.

## 1. Experimental Set-up and Data Samples at the 1999 Test Beam

Fig. 1 contains a schematic of the 1999 test-beam set-up. The muon beam traverses the set-up from the left. The silicon tracker STEL consisting of six silicon microstrip detectors with 7 $\mu$m resolution per plane was put behind the BOS chamber – contrary to last year's set-up – in order to avoid the absorption of shower particles by the STEL before they enter the chamber. The STEL served as high-precision external reference for muon tracks. Scintillator counters along the beam in front and behind the BOS chamber guarantee that the muons fly trough the entire absorber.

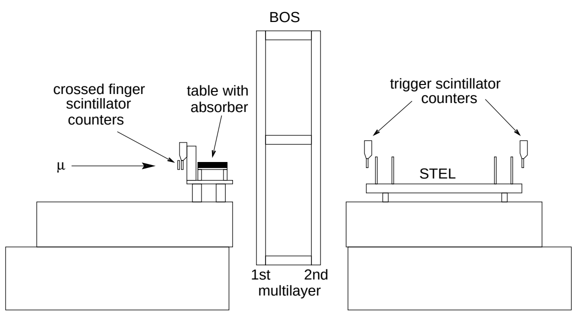


Fig. 1: Set-up at the 1999 test beam.

Data were taken at two beam energies, 100 GeV and 300 GeV (the highest available energy at H8). The choice of these energies was motivated by the energy dependence of the cross sections for the main processes responsible for the shower production; these are ionization, bremsstrahlung, and direct $e^+e^-$ pair production. Above 100 GeV, the cross section for ionization is constant whereas the cross sections of the others processes are rising linearily. Possible energy-dependend deviations of the simulated shower distribution from the experimentally observed distribution might be traced back to an insufficient simulation of one of these processes. To get more information, also the absorber length and the absorber material were changed during data taking.

At 100 GeV data with a 10 and 20 cm long iron and a 20 cm long aluminium bar of 6×6 cm$^2$ cross section were taken. At 300 GeV 5, 10, 20, 30 cm iron, and 10, 20, 30 cm aluminium aborbers were put into the beam.

## 2. Comparison of the Test-Beam Measurements with a GEANT 3.21 Simulation

The experimental data were compared to a GEANT 3.21 simulation. At 100 GeV beam energy experimental and simulated data agree quite well. The shape of the shower and the number of chamber hits caused by the shower particles are the same in Monte-Carlo as in data within 10%.

At 300 GeV the rate of events with shower hits is higher in the simulation than in real data, by about 20% in case of the iron absorber. For the aluminium absorber the rate is reproduced by the simulation. However in both cases, aluminium and iron, the Monte-Carlo produces too many shower hits per triple layer per event. In case of aluminium it increases linearily from 15% for 10 cm aluminium to 40% for 30 cm aluminium. In case of iron it is about 60% too high for all lengths.

## 3. Further Investigations

At the moment the observed discrepancy cannot yet be assigned to a special process. In order to understand the origin of the discrepancy of Monte-Carlo and real data, a simulation based on the new package GEANT-4 [3] is beeing prepared. It allows the incorporation of a more detailed discription of the direct $e^+e^-$ pair production and low-energy atomic processes connected to photons.

### References

[1] The ATLAS Muon Collaboration, ATLAS Muon Spectrometer, Technical Design Report, CERN/LHCC/97-22, 1997
[2] O. Kortner *et al.*, Results of the Analysis of the August 1998 Material Runs with Silicon Telescope, ATLAS-Muon-Note-99-009, München 1999.
[3] GEANT-4 collaboration, Geant4 User's Guide, Geneva 1999.