Calibration and performances of LHCf Arm2 upgraded detector for the reconstruction of hadronic events

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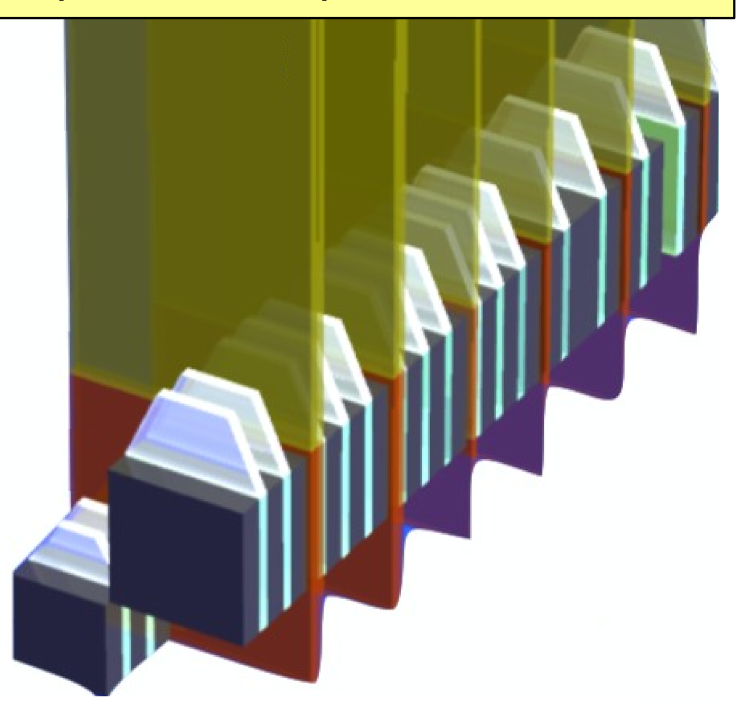
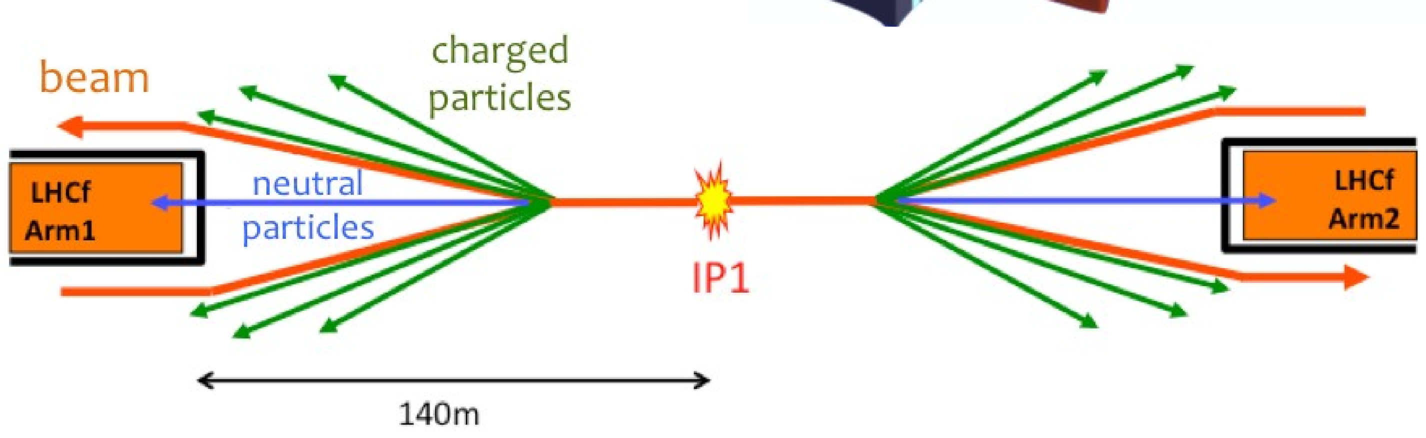
Abstract

The LHC-forward (LHCf) experiment [1] is intended to provide useful information for the calibration of hadron interaction models used by ground-based cosmic rays experiments. Among all neutral particles in the acceptance of LHCf, baryons have a particular importance because accurate measurements of their production rates can solve the “muon excess” problem observed in Extensive Air Showers [2]. Neutrons energy spectra for p-p collisions at $\sqrt{s}$ = 7 TeV have already been published by the collaboration [3], whereas the analysis of p-p collisions at $\sqrt{s}$ = 13 TeV is still ongoing. This last data set has been acquired in 2015 after a detector upgrade that was necessary to cope with higher radiation dose at this energy. In this poster we present the results for calibration and performances of the LHCf Arm2 upgraded detector for the reconstruction of hadronic events.

The LHCf experiment

The LHCf experiment consists in two different detectors, Arm1 and Arm2, installed in a region called TAN (Target Neutral Absorber), that is located at ±140 m from IP1 (ATLAS Interaction Point). Acceptance and shower containment are limited by the available room in this region. Particles reaching LHCf are neutral particles (mainly γ and neutrons) having pseudorapidity η between 8.4 and ∞. Both detectors are made up by two sampling calorimetric towers, each one consisting of 16 GSO layers alternated to 22 W layers. In the case of Arm2, towers sizes are 25 mm x 25 mm (*small tower*) and 32 mm x 32 mm (*large tower*), whereas their length is 29 cm, equivalent to 1.6 λ_I. In addition, 4xy position sensitive layers are placed at different depths in the calorimeter in order to reconstruct the lateral position of the primary particle. In the case of Arm2, this is performed using silicon microstrip detectors whose readout pitch is 160 μm.



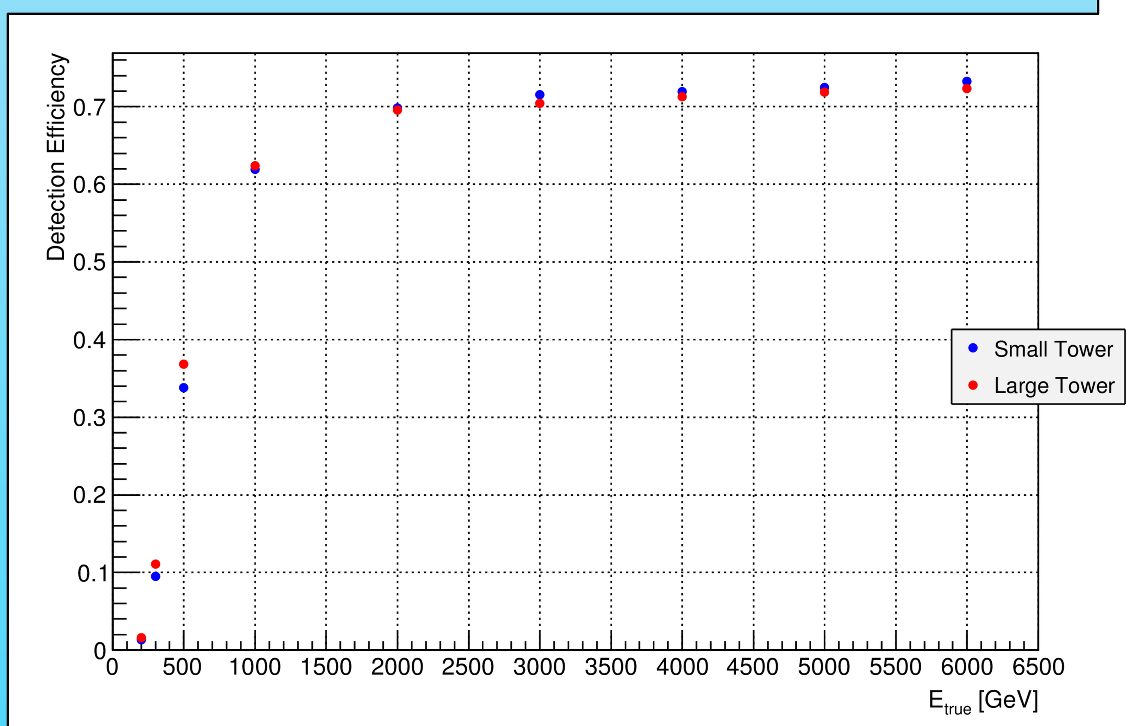


Performances

The performances of Arm2 upgraded detector have been studied using MC simulations obtained using DPMJet 3-0.4 model through COSMOS v7.645 and EPICS v9.165 libraries. For these studies we injected neutrons at the center of the tower in an energy range going from 100 GeV to 6 TeV.

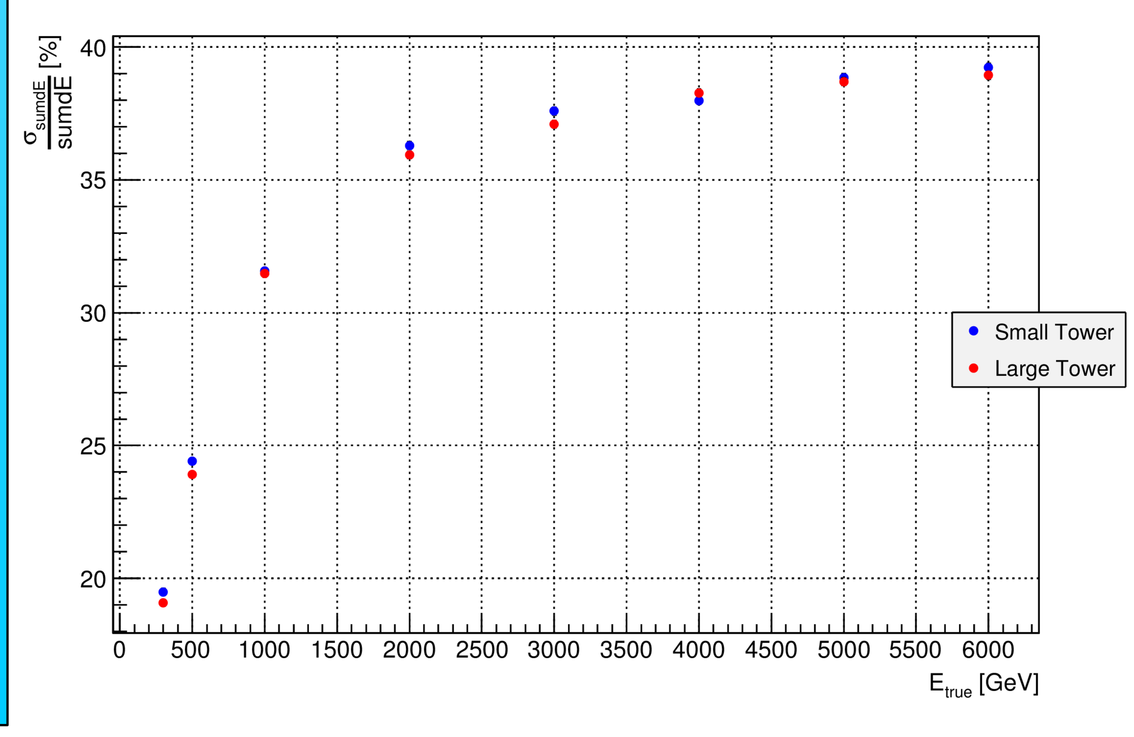
Detection efficiency

Because detector length is only 1.6 λ_I, it is necessary to define a trigger condition to reject weakly developed showers. The LHC hardware trigger condition requires a signal higher than a fixed discriminator threshold value for at least 3 consecutive scintillator layers. We established a **software trigger** condition similar to the hardware one, increasing the threshold to 600 MeV for all layers. As a result, detection efficiency is very small at low energy, then increases up to an approximately constant value of 70% above 2 TeV.



Energy resolution

Using this software trigger we estimated the energy resolution based on the *sumdE* parameter. *sumdE* represents the total energy deposited in the detector, weighting the contribution of each layer for the relative sampling step. The dominant factor in energy resolution is the **longitudinal leakage**, rapidly worsening the performances from 20% at low energy to 35% around 2 TeV. Above it, this contribution is mostly constant up to 6 TeV, so that resolution increases only slightly, reaching almost 40% at the highest energy.

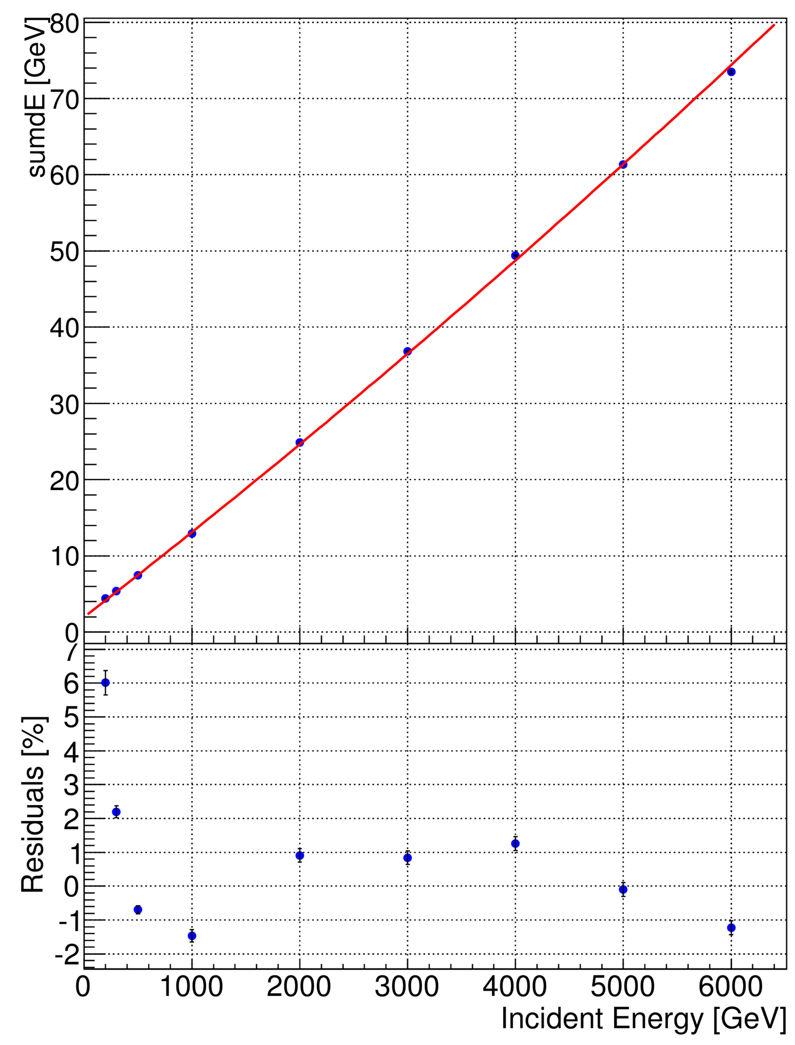


Calibration

In order to properly reconstruct the energy of the primary hadron, determination of conversion, correction and gain factors are necessary.

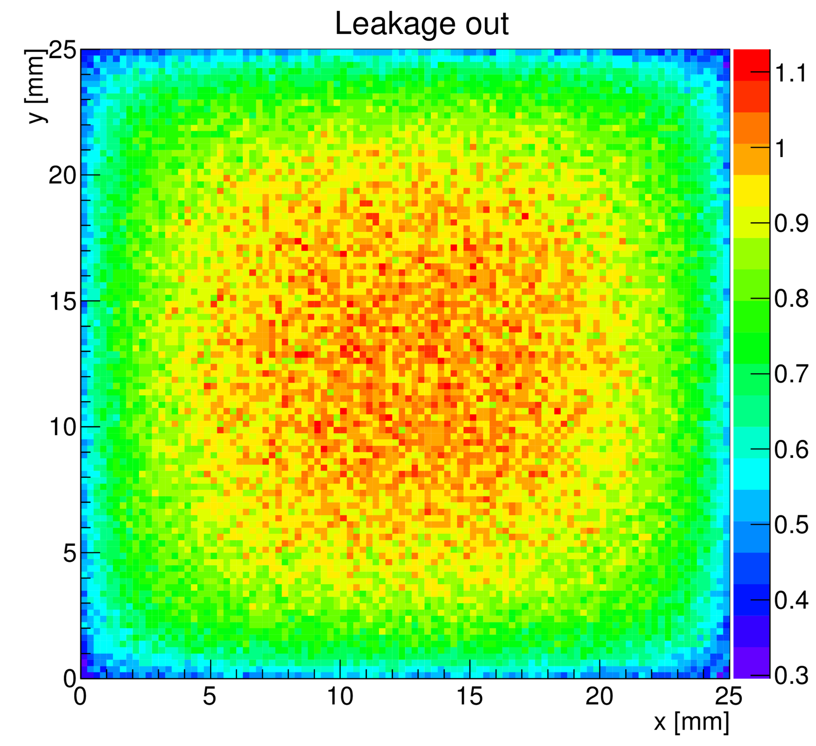
Energy conversion factors

Conversion factors from the deposited energy *sumdE* to the energy of the primary particle *E* were estimated using the same MC set previously described. Because the trigger condition is responsible for non linearity at low energy, we considered *sumdE* as a **second order polynomial function** of *E*. A systematic uncertainty of $\sigma_{ene.conv.}$**~2%** was estimated taking the maximum residual above 300 GeV.



Position dependent correction factors

Position dependent correction factors refer to two different contributions: **lateral leakage** and **light collection efficiency**. Both factors were estimated using MC simulations in which 1 TeV neutrons were uniformly injected on the tower area. Non-uniformity after correction was tested using 350 GeV protons beam data acquired at SPS. This variation was used as systematic uncertainty resulting in $\sigma_{pos.dep.}$**~3%**.

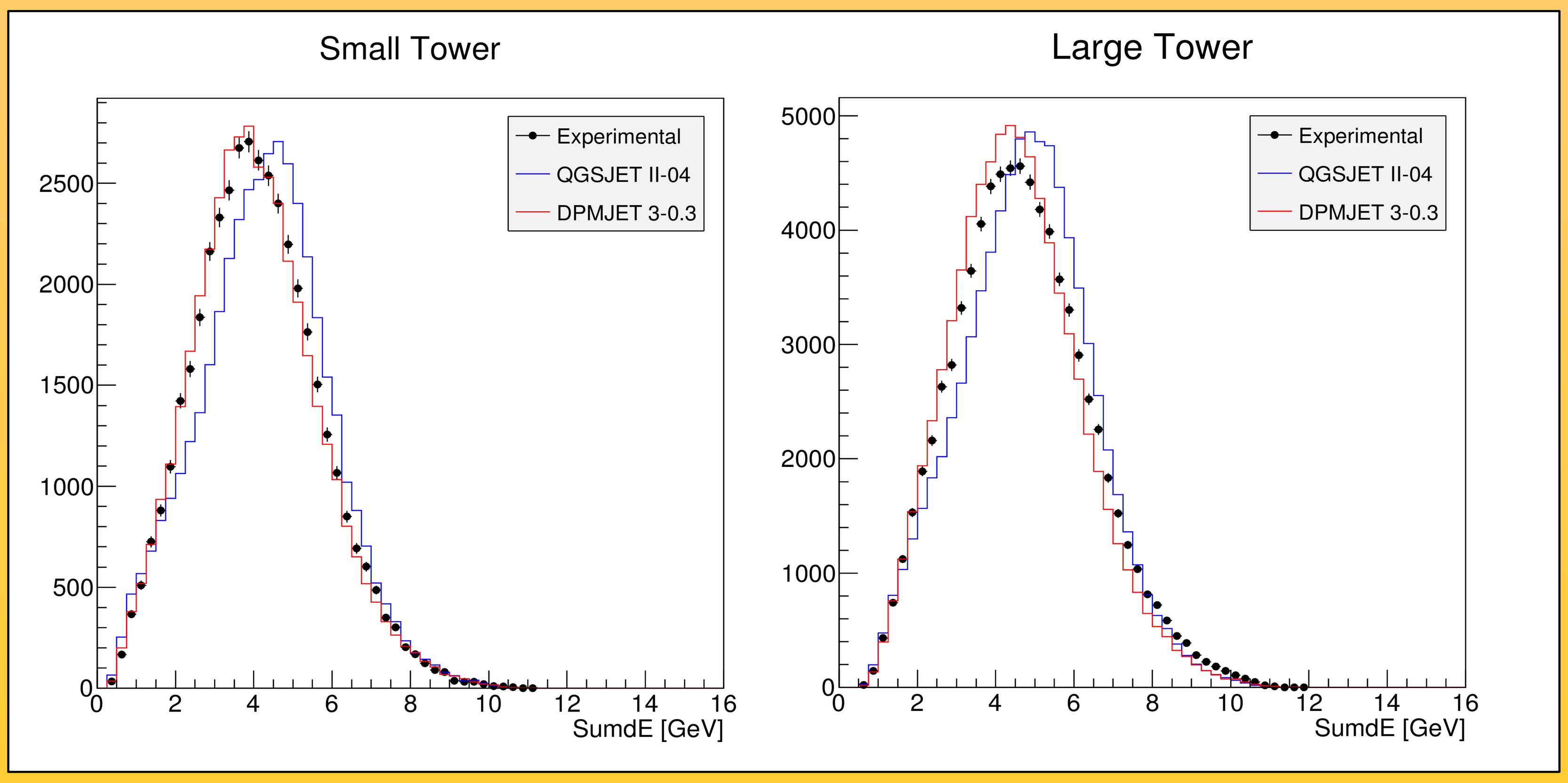


ADC/GeV gain factors

ADC/GeV gain factors for each scintillator layer were determined using **SPS data**. The first 12 layers were calibrated using **200 GeV electrons** beam, whereas the last 4 ones using **300 GeV protons** beam, resulting in a systematic uncertainty of σ_{gain}**~2%**.

Comparison with Models

All calibrations steps described so far were used to reconstruct **350 GeV protons data acquired at SPS** and to compare them with DPMJET 3-04 and QGSJET II-04 models. Here we changed the threshold value for the software trigger in order to scale 350 GeV to the typical energy of secondary neutrons from p-p collisions at $\sqrt{s}$ = 13 TeV. In addition we selected the rapidity regions that were used for the $\sqrt{s}$ = 7 TeV neutron paper: η>10.76 for *small tower* and 8.81 < η < 9.22 for *large tower*. After reconstruction, the deviation of data from the models prediction was estimated from the ratio of the means of the relative *sumdE* distributions. This led to an additional uncertainty of σ_{model}**~3.3%**.



Conclusions

Calibration of Arm2 upgraded detector for the reconstruction of hadronic events was studied. At first, all calibration factors were estimated, then beam test data were compared to models prediction. Considering all contributions as independent, we obtained a total systematic uncertainty on the energy scale of σ_{energy}**~5.3%**. In parallel, we investigated detector performances using simulations. Detection efficiency and energy resolution resulted to be mostly constants for neutrons above 2 TeV, at a value of ~70% and ~40% respectively.

References

[1] The LHCf Collaboration et al., JINST 3.08 (2008), S08006
[2] J. Allen et al., Proceedings of 32nd ICRC, Beijin (2011)
[3] K. Kawade et al., JINST 9.03 (2014), P03016