Proposal to upgrade the very forward region at CMS

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Abstract
The possibilities of extending the acceptance of LHC experiments beyond 7 units of pseudorapidity are investigated. With additional detectors it would be possible to measure the particles with energies above 2 TeV in the pseudorapidity range between 7 and 11.

1 Introduction

At the LHC experiments, CMS and ATLAS, the acceptance for forward energy measurements is limited to about 5 units of pseudorapidity. The acceptance of CMS detector will be extended by proposed CASTOR calorimeter, which will cover the angular range $5.4 < \eta < 6.7$. Already with this device small-x parton dynamics can be studied down to very small x-values of $10^{-6} - 10^{-7}$ with Drell-Yan, prompt photon and jet events at small invariant masses of the order of $M \sim 10$ GeV.

In the present work we investigate the technical possibilities of extending the angular acceptance for forward energy measurement beyond 7 units of pseudorapidity. Extending the acceptance down to $\eta \sim 11$, x-values down to 10^{-8} can be reached, which is a completely unexplored region of phase space. In this region, effects coming from new parton dynamics are expected to show up, as well as effects coming from very high density gluonic systems, where saturation and recombination effects will occur. In this region of phase space, a breakdown of the usual factorization formalism is expected, and multiple

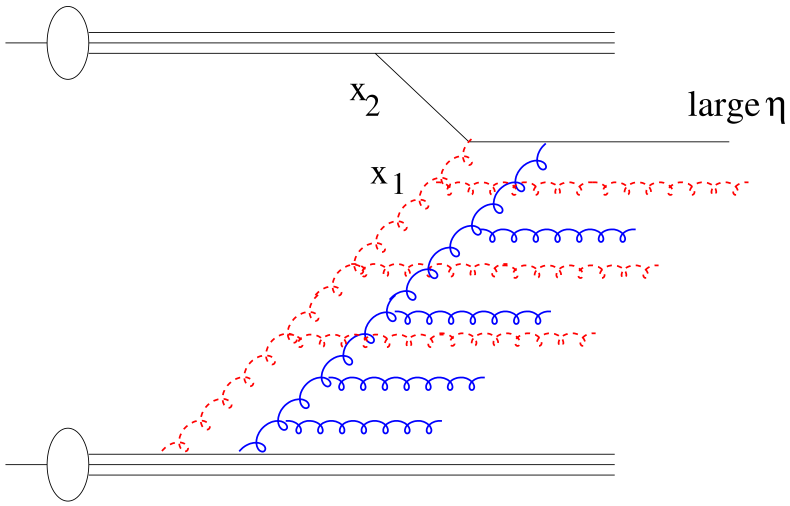

Fig. 1: Schematic picture of multiple interactions at small x

interactions will be dominant (see Fig 1) [1]. The full angular coverage from the central to the most forward region allows a systematic study of the transition from single particle exchange processes to complex systems and a systematic understanding of non-linear and collective phenomena.

The interest in the very forward region of phase space is not only motivated by the fundamental understanding of QCD in a new phase of matter, but is also important for the further understanding of high energetic cosmic rays [2].

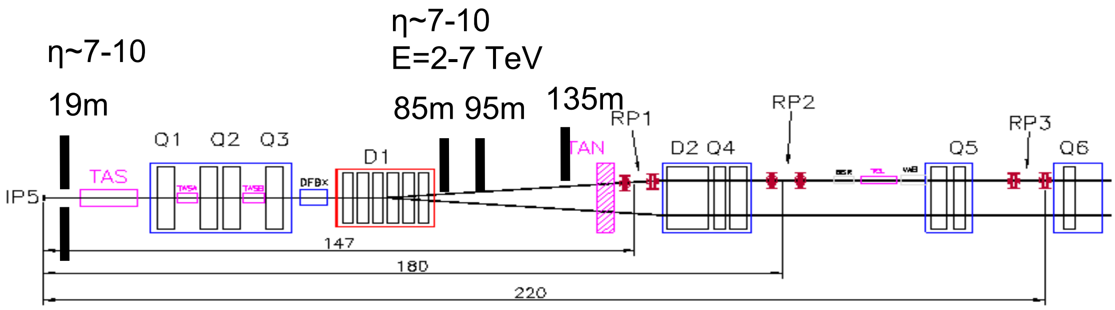

Fig. 2: Schematic view of forward beamline at CMS detector up to 220m. The positions of proposed tracking devices at 19m, 85m and 95m and calorimeter at 135m are indicated.

2 Tracking and energy measurement in the very forward region

For this study the geometry of the beam-line around the CMS detector up to 150m from interaction point has been implemented in the GEANT-3 [3] simulation program. The PYTHIA Monte-Carlo generator program [4] was used to generate charged particles produced in the interaction point, which were subsequently fed into the beam-line simulation.

The main restriction for additional installations is the very limited space available between magnetic elements. Up to about 80m there is no space for a calorimeter, and there one can only consider the installation of tracking devices, such as Roman Pots or micro-stations [5]. On the other hand, to be able to measure the particle momenta, the tracking devices should be placed after bending magnets.

Therefore the idea is to have tracking devices before and after dipoles, to be able to measure both the integrated particle flow and the particle momenta. The free space after 135 m can be used for a calorimeter.

Taking into account the limited space available for new detectors, the background conditions and magnetic field, the following strategy is proposed (Fig.2):

– the 25 cm space in front of TAS absorber at 19 m from interaction point can be used to install two micro-stations with two half-ring radiation hard silicon or diamond detectors approaching the beam horizontally up to 5-10mm. At this position the particles can not be separated by their momenta, thus the micro-stations will measure the charged particle flow integrated up to energies of ~ 7 TeV in the pseudorapidity range between 7.3 and 9 or 10.5, depending on how close the counter can go to the beam (see Fig. 3). The detector will also provide accurate position measurement which is necessary for linking with roman-pots/micro-stations installed further down the beam line. Combining the position and time-of-flight measurement of these micro-stations with the event vertex measured in central detector will allow to suppress beam-wall background and pile-up events;
– a combination of two horizontal roman-pots/micro-stations can be installed behind the dipole magnets D1 at 85m and 95m. The detectors are the half-rings and approach the beam horizontally from one side up to 10mm. These detectors will cover the pseudorapidity range above 8 units (see Fig. 5). The particles with energies below 2 TeV will escape the detector acceptance, as shown in Fig. 4 and 5.
– a hadronic calorimeter at 135m (in front of TAN iron absorber) with a minimal distance to the beam of 10cm (radius of beam-pipe) will measure the energy in the range 2-5.5 TeV and pseudorapidity between 7 and 11 (see Fig.6). This can be a sandwich type calorimeter with radiation hard sensitive layers, with a transverse size up to $1\times1\ m^2$ and depth about 7-9 hadronic interaction length. Optionally one can consider to instrument the TAN absorber with sensitive layers.

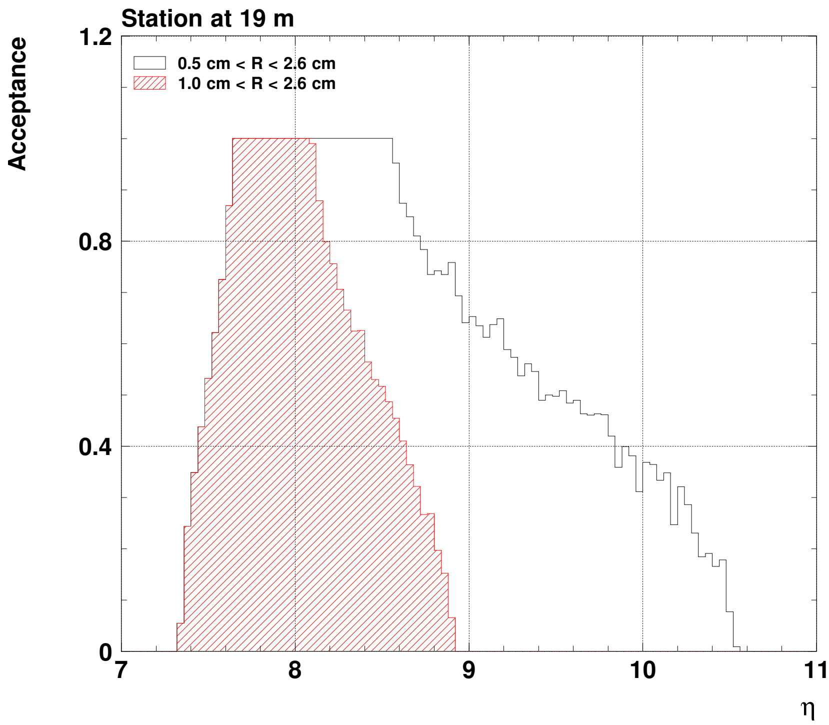

Fig. 3: Acceptance of micro-station detector at 19m as a function of pseudorapidity.

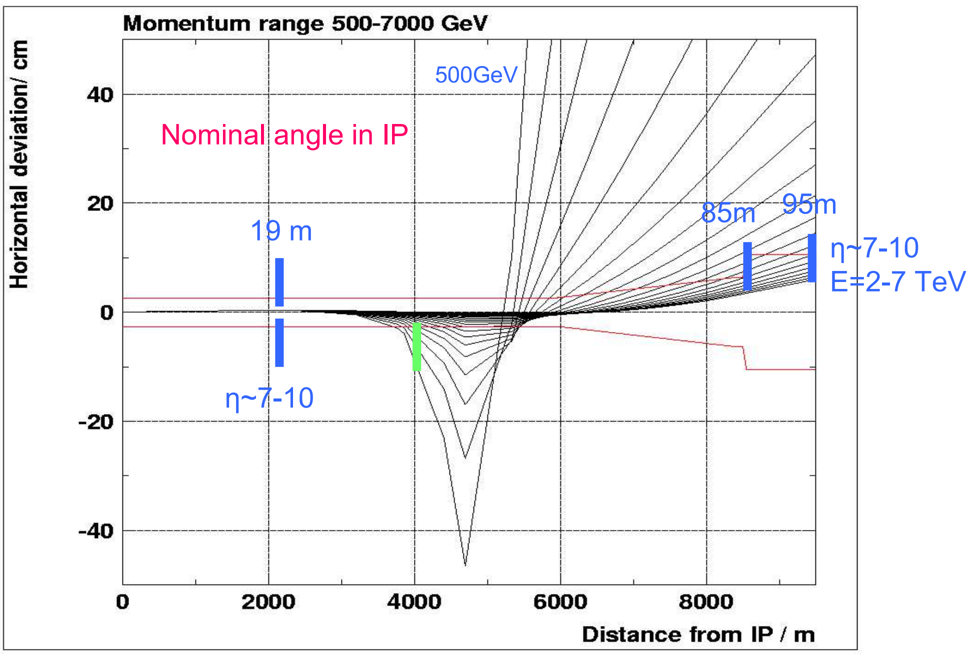

Fig. 4: The trajectory of particles in momentum range 500-7000 GeV, scattered from interaction point at 0 deg. The positions of proposed tracking devices at 19m, 85m and 95m are indicated.

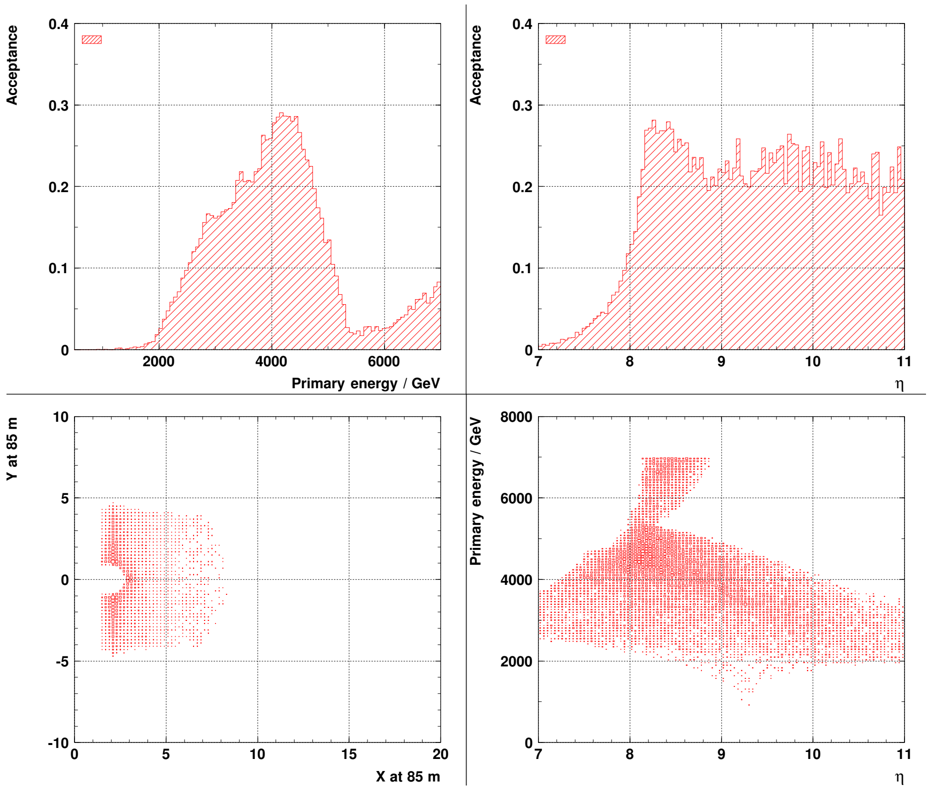

Fig. 5: Acceptance of roman pots/micro-station detector at 85 m and 95m as a function of energy and pseudorapidity.

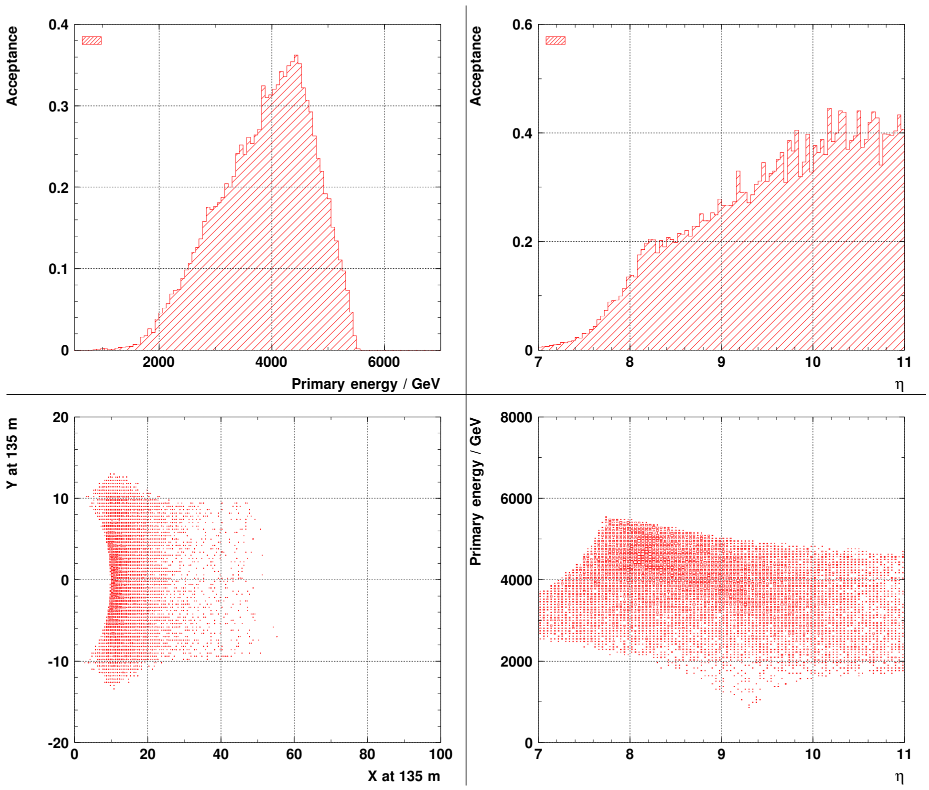

Fig. 6: Acceptance of calorimeter at 135 m as a function of energy and pseudorapidity.

The calorimeter covers basically the same kinematic range as the micro-stations at 85 and 95m, but it is needed for energy measurement. In addition it can be used for redundancy, background subtraction and cross calibration.

The acceptances of the proposed detectors as function of energy and pseudorapidity are summarized in Table 1. The result shows that with the proposed installations it will be possible to measure the energy flow in the energy range between 2 and 7 GeV and the pseudorapidity range between 7 and 11.

Table 1: Acceptance as a function of E_p and η

	0.5–7 TeV	2–5.5 TeV
two roman-pots/micro-stations at 85 and 95m		
$\eta = 7 - 10$	11%	21%
$\eta = 7 - 8$	10%	10–20%
$\eta = 8 - 9$	15-25%	30–55%
$\eta = 9 - 11$	20-25%	55–60%
Calorimeter at 135m		
$\eta = 7 - 8$	15%	25%
$\eta = 8 - 9$	20-25%	35–55%
$\eta = 9 - 11$	25-40%	45–60%

To be able to measure the particles with momenta below 2 TeV one would need to install detectors in the cold area between the quadrupoles at 40–50 m. This will require essential modifications of cryogenic lines, and can be considered for a future upgrade program.

3 Conclusions

We have studied the possibilities of extending the angular acceptance for forward energy measurement at LHC. With additional roman-pots/micro-stations and a calorimeter it will be possible to measure the forward energy in the rapidity range between 7 and 11 units. Such installation will be a valuable addition to the LHC physics program.

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