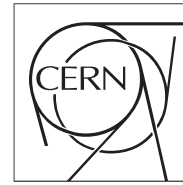


The Compact Muon Solenoid Experiment
Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland



26 April 2008

Soft physics capabilities of CMS in p-p and Pb-Pb

Ferenc Siklér for the CMS Collaboration

Abstract

The CMS experiment will provide good quality measurements of yields and spectra of identified charged and neutral particles, both in p-p and heavy-ion collisions, thus contributing to the study of soft hadronic physics at the LHC energies.

Presented at *Quark Matter 2008 Conference, 4-10 February 2008, Jaipur, India*

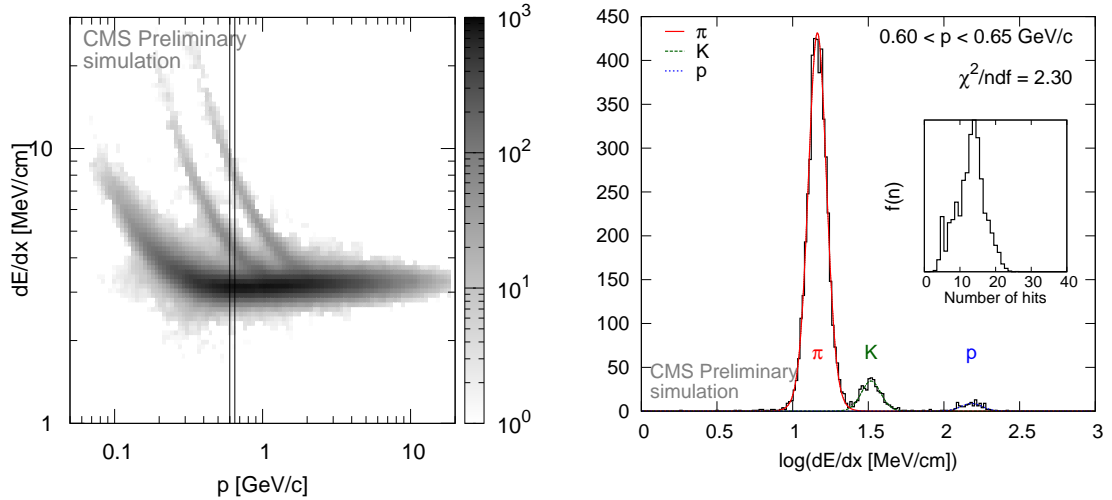


Figure 1: Left: Distribution of the truncated mean estimator dE/dx as a function of momentum p . Right: Example fit of the $\log(dE/dx)$ histogram in the indicated momentum bin. The distribution of the number of hits on track $f(n)$ is also given.

The CMS experiment at the LHC is a general purpose detector designed to explore physics at the TeV energy scale [1]. It has a large acceptance and hermetic coverage. The various subdetectors are: a silicon tracker with pixels and strips ($|\eta| < 2.4$); electromagnetic ($|\eta| < 3$) and hadronic ($|\eta| < 5$) calorimeters; and muon chambers ($|\eta| < 2.4$). The acceptance is further extended with forward detectors: CASTOR ($5.3 < |\eta| < 6.6$) and Zero Degree Calorimeters ($|\eta| > 8.3$). CMS detects leptons and both charged and neutral hadrons. In the following the soft physics capabilities are described. For an extensive review see Ref. [1].

One of the first physics results from the LHC will be the measurement of charged hadron spectra in p-p collisions. The measurement of these basic observables will also serve as an important tool for the calibration and understanding of the CMS detector and will help establishing a solid basis for exclusive physics. This example analysis uses 2 million inelastic p-p collisions. They have been generated by the PYTHIA event generator [2].

The p-p minimum bias trigger will be based on counting towers with energy above the detector noise level, in both forward hadronic calorimeters (HF, $3 < |\eta| < 5$). A minimal number of hits (1, 2 or 3) will be required on one or on both sides, an energy threshold value of 1.4 GeV is used in the hit definition. Once the luminosity is high enough, events can also be taken with the so called zero-bias trigger: a random (clock) trigger.

The Pb-Pb trigger will be similar since there are many particles produced in the region of the forward calorimeters. In that case the event centrality will be determined using both HF and CASTOR calorimeters in combination with the energy measurement of forward spectator neutrons in both ZDCs.

A good measurement of differential and integrated yields requires particle tracking down to as low p_T values as possible. With a modified algorithm the pixel detector can be employed for the reconstruction of very low p_T charged particles. The acceptance of the method extends down to 0.1, 0.2 and 0.3 GeV/c in p_T for pions, kaons and protons, respectively. The obtained proto-tracks are used for finding and fitting the primary vertex or vertices. The measured shape and width of hit clusters are compared to the dimensions predicted from the local direction of the trajectory. This filter helps to eliminate incompatible trajectory candidates at an early stage. The seeds the trajectory building starts from are very clean, hence one seed is expected to produce only one global track. At the end, the tracks are refitted with the primary vertex constraint. For details see Refs. [1, 3, 4].

The hadron spectra are corrected for feed-down from weakly decaying resonances (K_S^0 , Λ and $\bar{\Lambda}$). A recorded event is used in the analysis if it passes offline track or vertex triggers. In the case of single inelastic events, the probabilities to reconstruct zero, one or two interaction vertices are 22%, 74% and 4%, respectively.

Charged particles can be singly identified or their yields can be extracted using deposited energy in the pixel and strip silicon tracker (Fig. 1-left). The bands of pions, kaons and protons are well visible. The distribution of the logarithm of the estimator can be fitted in slices of momentum (see Fig. 1-right). The relative resolution of dE/dx

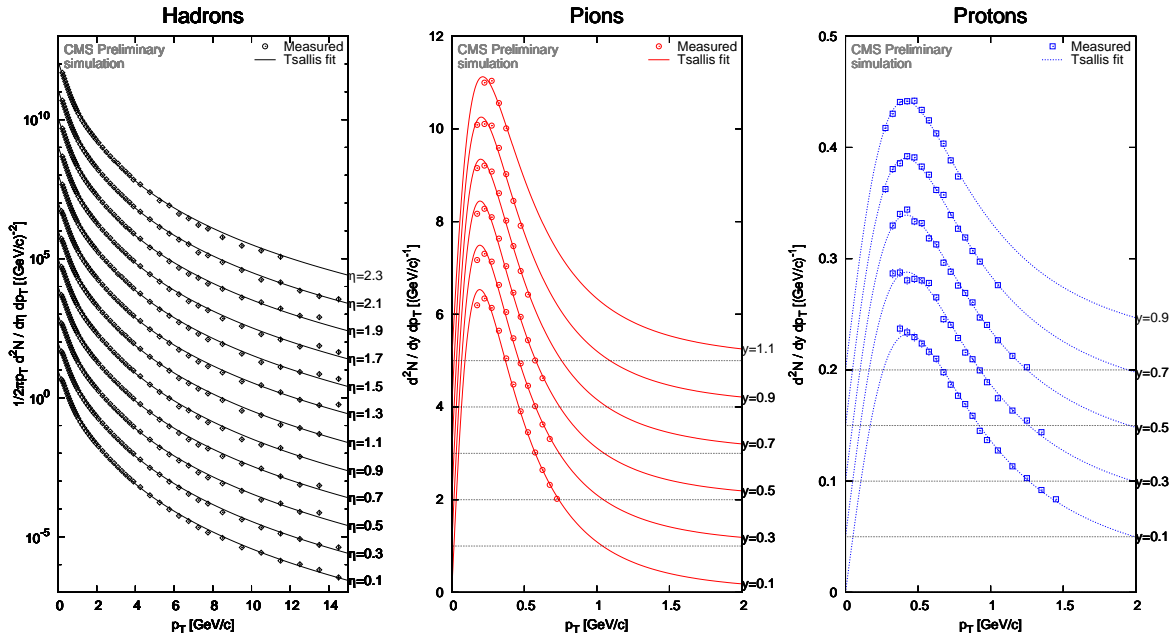


Figure 2: Measured invariant and differential yields of charged hadrons, pions and protons in a series of 0.2 unit wide η or y bins. For charged hadrons values are successively multiplied by 10. For identified hadrons values are successively shifted upwards by one unit for clarity. Measured values and empirical fit functions are plotted.

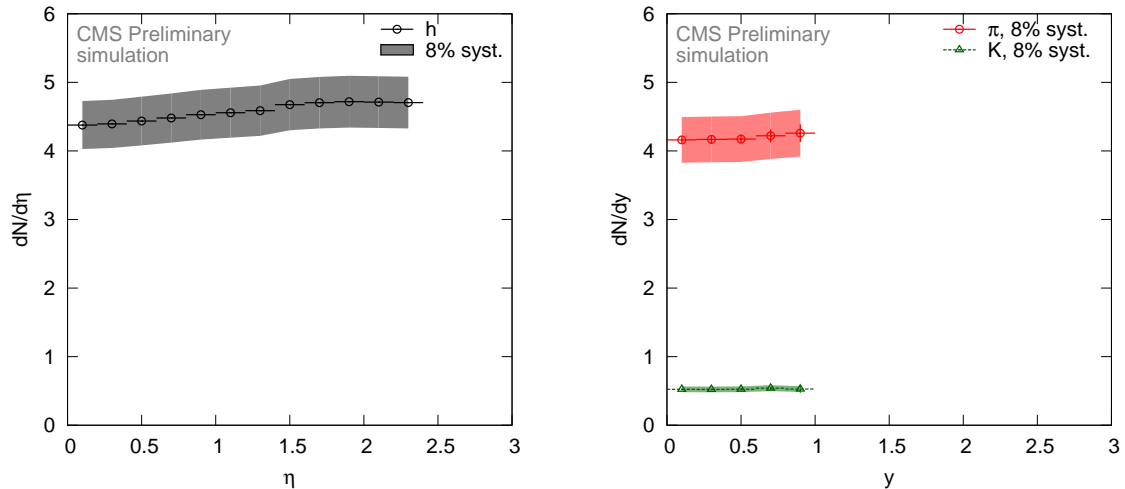


Figure 3: Left: Pseudorapidity distribution of charged hadrons. Right: Rapidity distribution of charged pions and kaons. Estimated systematic error bands (8%) are also shown.

for tracks with average number of hits (~ 15) is around 5-7%. The result shows that the yield of kaons can be extracted if $p < 0.8$ GeV/c and that of protons if $p < 1.5$ GeV/c. Both limits correspond to approximately 3σ separation. Details can be found in Ref. [5].

The invariant yields were fitted by the Tsallis function [6]. In general, results refer to the sum of positively and negatively charged particles. Measured invariant and differential yields of charged hadrons are shown in Fig. 2. The pseudorapidity distribution of charged hadrons (Fig. 3-left) and the rapidity distributions of pions and kaons are shown in Fig. 3-right. The energy dependence of some measured quantities can also be studied (Fig. 4). More details can be found in Ref. [5].

The reaction plane in Pb-Pb collisions can be reconstructed using electromagnetic and hadronic calorimeters, by extracting harmonic angular coefficients of the energy deposition distribution [1]. The second harmonic coefficient v_2 can also be determined using the silicon tracker with an estimated systematic error below 3%.

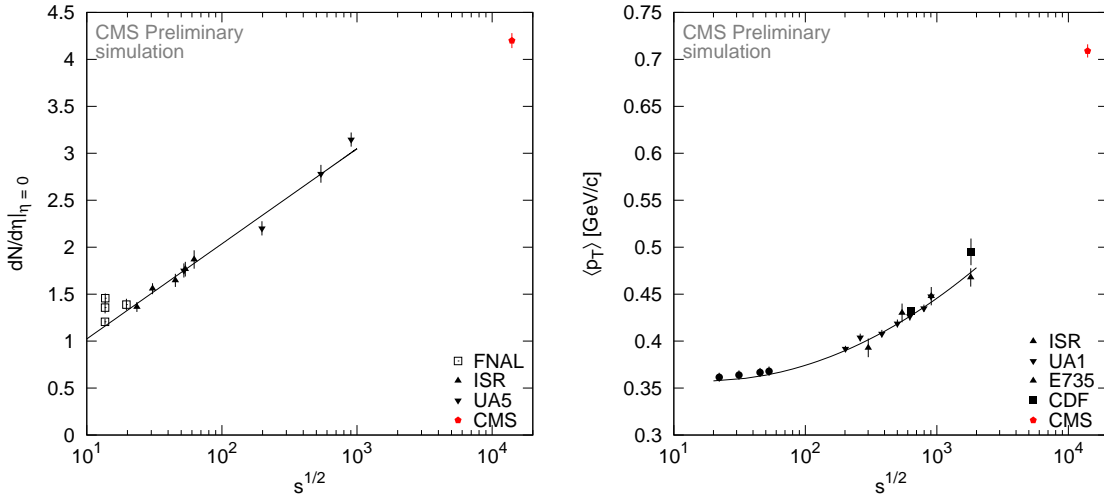


Figure 4: Left: Energy dependence of pseudorapidity density of charged hadrons at $\eta \approx 0$. Right: Energy dependence of average transverse momentum of charged hadrons at $\eta \approx 0$. The lines show the fit to data points of other experiments taken from Refs. [7, 8]. Results of this analysis are shown with pentagons in the top right corner.

In summary, the CMS detector has a good capability for global event characterization and physics with soft probes. The performance in low bias triggering, measurement of charged hadron spectra and yields, particle identification and elliptic flow have been shown.

Acknowledgment

The author wishes to thank the Hungarian Scientific Research Fund and the National Office for Research and Technology (K 48898, H07-B 74296).

References

- [1] D. d’Enterria *et al.*, “CMS physics technical design report: Addendum on high density QCD with heavy ions,” J. Phys. G **34** (2007) 2307.
- [2] T. Sjostrand, S. Mrenna and P. Skands, “PYTHIA 6.4 physics and manual,” JHEP **0605** (2006) 026 [arXiv:hep-ph/0603175].
- [3] F. Sikler, “Low p_T hadronic physics with CMS,” Int. J. Mod. Phys. E **16** (2007) 1819 [arXiv:physics/0702193].
- [4] F. Sikler [CMS Collaboration], “Soft probes of high density QCD physics with CMS,” J. Phys. G **35** (2008) 044045 [arXiv:0710.1874, nucl-ex].
- [5] The CMS Collaboration, “Measurement of charged hadron spectra in proton-proton collisions at $\sqrt{s} = 14$ TeV”, CMS Physics Analysis Summary **QCD-07-001**.
- [6] C. Tsallis, “Possible Generalization of Boltzmann-Gibbs Statistics,” J. Statist. Phys. **52** (1988) 479.
- [7] G. J. Alner *et al.* [UA5 Collaboration], “Scaling of Pseudorapidity Distributions at c.m. Energies Up to 0.9-TeV,” Z. Phys. C **33** (1986) 1.
- [8] T. S. Ullrich, “Experimental summary on global observables, hadron spectra and ratios,” Nucl. Phys. A **715** (2003) 399 [arXiv:nucl-ex/0211004].