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Results on charged particle production from the ALICE experiment at LHC

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The ALICE experiment participated successfully at the first data taking with pp collisions at the CERN Large Hadron Collider. Data collected at the highest ever reached collisional energies are used to study the production of charged particles at central rapidity. The measurements are based on the information provided by the ALICE Time Projection Chamber and the silicon Inner Tracking System. We discuss the primary charged particle pseudorapidity density at three different center of mass energies, and their inclusive transverse momentum differential yields at 900 GeV. Comparisons with other measurements in proton-antiproton collisions at 900 GeV, and with model predictions are discussed.

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1. Introduction

The Large Hadron Collider (LHC) [1] at CERN started delivering proton-proton collisions in November 2009. The accelerator, unique in its size and energy reach, rapidly moved from collisions at injection energy (0.9 TeV), to 2.36 TeV (in December) and then to the highest ever reached center of mass energy of 7 TeV (in March 2010). All LHC experiments had profited from extensive data taking campaigns with cosmic rays in the previous months. With these, the calibration and alignment of all important subdetectors was already extremely advanced at the moment of the LHC startup. The ALICE experiment [2] immediately addressed various aspects of charged particle production in proton-proton collisions. This can be properly described only considering both soft and hard interactions. Perturbative QCD, which describes parton-parton interactions at large momentum transfers, i.e. hard scattering processes, is therefore not sufficient to model all aspects of particle production. It has to be combined with phenomenological approaches which model the soft component of the produced particle spectrum. This is done in current models of hadron-hadron collisions at high energies, such as the event generators PYTHIA [3] and PHOJET [4], but they still need to be tuned with the new experimental results collected at LHC in order to properly describe particle production at the highest LHC energies.

This contribution presents the first measurements by the ALICE Collaboration of charged particle pseudorapidity density at central rapidity for all three collisional energies [5], [6], [7], and the transverse momentum distribution of charged particles at 0.9 TeV [8]. ALICE has also already demonstrated its remarkable potential concerning particle identification over a very large momentum range, which will soon allow the measurement of identified particle spectra and particle ratios with high precision. After a brief introduction to the experiment and the first data samples used, follows the discussion of the first results, and we conclude with a brief overview of the physics analyses in preparation.

2. The ALICE Experiment and Data Collection

ALICE (A Large Ion Collider Experiment) is a large, general purpose experiment designed in particular to study the properties of the hot and dense matter produced in the collisions of heavy ions, the Quark Gluon Plasma. The experiment includes a barrel part located inside the L3 solenoidal magnet (which provides a uniform 0.5T field), as well as a muon spectrometer. A detailed description can be found in [2]. For the measurements presented here, the barrel part of the experiment was involved and in particular the silicon vertex detector (Inner Tracking System, ITS) and the Time Projection Chamber (TPC).

The ITS includes 6 cylindrical layers, two of silicon pixels (SPD), two of drift (SDD) and two of microstrip detectors (SSD), located very close to the interaction region (from 3.9 to 43 cm radius) to provide extremely high resolution on track, as well as on primary and secondary vertex reconstruction. A very precise alignment of the ITS is being performed using survey measurements, cosmic muon data [9] and collision data. A resolution of about 60 μm on the impact parameter of tracks with 1 GeV/c transverse momentum is achieved.

The TPC [10] is the world largest of its kind and provides precise track momentum reconstruction as well as excellent particle identification via the measurement of the deposited energy per track unit length. Already at the experiment startup, thanks to the calibration done with cosmic rays, a momentum resolution better than 1% for tracks of 1 GeV/c was reached.

Data used for these analyses were collected at the three different collisional energies, with relatively low intensity proton bunches, and only one or few colliding bunches at the ALICE interaction point. In these conditions pile-up and background from beam and cosmic rays were either negligible or easy to correct for. An exhaustive discussion of this issue can be found in [5].

The ALICE trigger required a hit in the two innermost layers of silicon pixel detectors (the SPD, covering the pseudorapidity range $|\eta|<2$ and $|\eta|<1.4$ with the inner and the outer layer, respectively) or in either one of two scintillator hodoscopes placed on the two sides of the interaction region. The combination covers in total about 8 units in rapidity; the exact trigger settings varied slightly for the different data samples. In addition, the events were in coincidence with signals from 2 beam pick-up counters, also on the two sides of the interaction region, indicating the passage of proton bunches.

At the time of the conference, ALICE has collected roughly 470 thousand minimum bias events at 0.9 TeV, 30 thousand at 2.36 TeV and almost 20 million events at 7 TeV.

3. Charged Particle Pseudorapidity Density

One of the first properties of hadronic interactions to be studied is multiparticle production, which is measured via the pseudorapidity density of charged primary particles in the central rapidity region. Primary particles include particles produced in the collision and their decay products, except those from weak decays of strange hadrons. Multiparticle production is rather successfully described by phenomenological models, which relate the energy dependence of the total cross section to that of the multiplicity production: having data from three different collisional energies gives a unique opportunity to verify the model predictions, as well as to compare to different Monte Carlo event generators which describe soft hadron collisions, based on the same models. The results at 0.9 TeV can also be compared to those from $p\bar{p}$ collisions at the same energy.

The final analysis comparing the particle multiplicities at 0.9, 2.36 and 7 TeV, was done on a selection of inelastic events with at least one track in the pixel detector within $|\eta|<1$ and a reconstructed vertex in a nominal region (within ± 5.5 cm from the detector center along the beam direction). This choice reduces sensitivity to model dependent corrections. A detailed description of the analysis and the discussion of the results are presented in [5]-[7] and references therein.

Figure 1 shows the charged particle pseudorapidity density in the central region $|\eta|<1$ for the selected event class (INEL>0, along the top dashed line), as a function of the centre of mass energy. Other results for inelastic and non-single-diffractive events are shown for ALICE in comparison to other experiments. The lines indicate the fit using a power-law dependence on energy.

The ALICE results from proton-proton interactions are consistent with those from proton-antiproton collisions (from the UA5 experiment), as expected from the fact that the predicted difference (0.1-0.2%) is below measurement uncertainties.

In order to evaluate the center of mass energy dependence, we have considered the relative increase of pseudorapidity densities between the measurement at 0.9 TeV and the measurements at 2.36 and 7 TeV, and we compare this relative increase with the one predicted by the most commonly

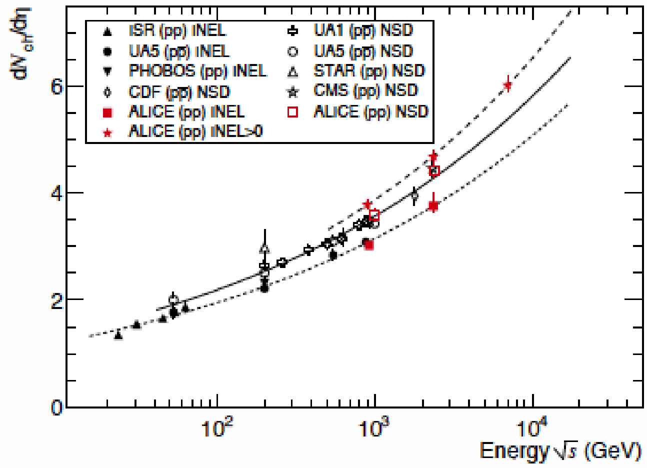

Figure 1: Charged particle pseudorapidity density at central rapidity, for various event classes, as a function of the centre of mass energy (see [7] for more details). Data points at the same energy have been slightly shifted horizontally for visibility.

used models. We have used two different Monte Carlo event generators, PYTHIA (tunes Perugia-0, ATLAS-CSC and D6T) and PHOJET. We observe an increase of $57.6\% \pm 0.4\%$ (*stat.*) $^{+3.0}_{-1.8}\%$ (*syst.*) between the 0.9 TeV and 7 TeV data. This largely exceeds the predictions by all models considered, as shown in figure 2. The measured multiplicity density grows with increasing energy significantly faster than in any prediction. This is a first very important input to tune the models to properly describe the interactions at the highest energies.

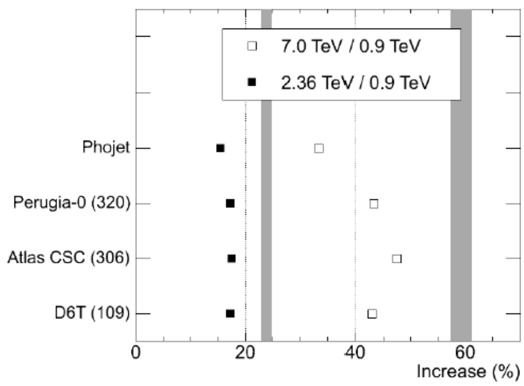

Figure 2: Relative increase of the charged particle pseudorapidity density, for inelastic collisions with at least one charged particle in $|\eta|<1$, between $\sqrt{s}$=0.9 TeV and 2.36 TeV (open squares) and between $\sqrt{s}$=0.9 TeV and 7 TeV (full squares), for various models. The ALICE measurements are shown with vertical dashed and solid lines [7].

4. Charged Particle transverse Momentum Spectrum

The transverse momentum spectrum of charged particles produced in hadronic interactions is extremely interesting to study the combination of soft and hard processes. We present here the spectrum measured for primary particles produced in proton-proton collisions at 0.9 TeV recorded by ALICE in December 2009. The detailed description of the analysis and discussion of the results can be found in [8].

Charged particle tracks are reconstructed with excellent precision by combining the information from the TPC and the ITS, in the central rapidity region $|\eta|<0.8$ (where tracks in the TPC can be reconstructed with maximal length, and there are minimal efficiency losses due to detector boundaries). The measurement covers the p_T range $0.15 < p_T < 10$ GeV/c, where both hard and soft processes are expected to contribute to particle production. Below 0.15 GeV/c the track reconstruction efficiency drops below 50%.

The particle transverse momentum is measured in the TPC, taking into account energy loss based on the particle identification hypothesis from the TPC dE/dx, and the material budget in front of the TPC, known with the precision of a few percents.

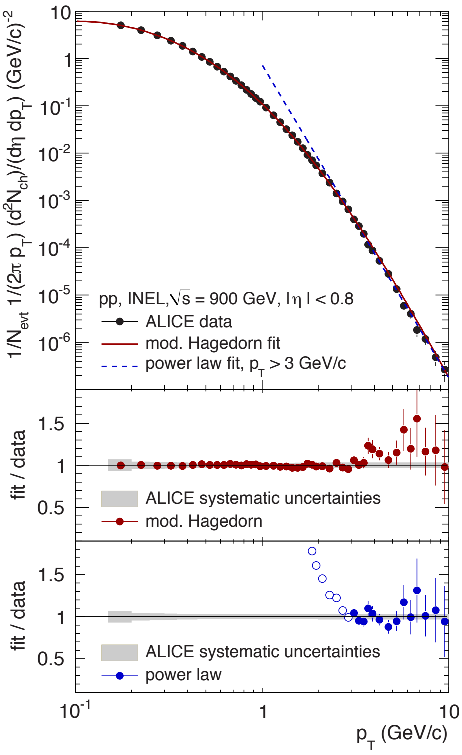

Figure 3: Normalized differential primary charged particle yield in inelastic events, within $|\eta|<0.8$. The fit ranges are $0.15<p_T<3$ GeV/c for the modified Hagedorn function and $3<p_T<10$ GeV/c for the power law. In the lower panels, the ratios fit over data are shown [8].

We estimate corrections for acceptance and efficiencies with Monte Carlo simulations.The fully corrected spectrum is then fitted by the modified Hagedorn function up to transverse momenta of 3 GeV/c. For higher transverse momenta, a power law fit is performed to better describe the hard part of the spectrum.

The corrected spectrum for inelastic events and the fits are shown in figure 3. As shown in the two lower panels, the modified Hagedorn function and the power law fit provide a good description of the spectrum in the two different transverse momentum ranges. The former is also used to perform the extrapolation to p_T=0 GeV/c.

We also study the correlation between the average transverse momentum (for $|\eta|$<0.8) and the event particle multiplicity. For inelastic events, we measure $<p_T>_{INEL}$ = 0.483 $\pm$ 0.001 (*stat.*) $\pm$ 0.007 (*syst.*) GeV/c. The ALICE result exhibits a slightly larger $<p_T>$ than measurements in wider pseudorapidity intervals by the ATLAS, CMS and UA1 ($p\bar{p}$) experiments. This is due to the different pseudorapidity intervals (narrower in the ALICE case).

The transverse momentum spectrum is compared to simulations done with both PHOJET and PYTHIA with the tunes D6T, Perugia-0 and ATLAS-CSC. The best agreement is found with the Perugia-0 tune: the spectral shape is described well, although the prediction is about 20% below the data. Other tunes and PHOJET fail to reproduce the spectral shape from the data. Again, the experimental results are a vital input in order to tune the phenomenological models.

5. Conclusions

We have presented the first measurements of multiparticle production by the ALICE experiment at the LHC. The results from charged particle pseudorapidity densities and transverse momentum distributions at mid rapidity are an essential input to tune the models which aim at describing the fundamental properties of hadronic collisions at the highest ever reached energies. After this brilliant startup of physics at the LHC, ALICE is preparing the analysis of identified particle spectra, particle ratios, two-pion Bose-Einstein correlations, heavy flavor and jet production, just to mention a few of the many topics which will be addressed in the near future. The proper understanding of the apparatus as well as the physics analyses in proton-proton collisions, are the important baseline for the rich program of heavy ion physics, focus of the ALICE experiment.

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