Experimental summary of ISMD10

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This paper summarizes the main experimental results presented at the XL International Symposium on Multiparticle Dynamics (ISMD10, 21-25 September 2010 University of Antwerp,Belgium).

1 Introduction

Almost ten years ago, my colleague from ANL, Malcolm Derrick, during his summary speech at the International Symposium on Multiparticle Dynamics in 1999 (ISMD99, the Brown University), summarized concerns about the LHC construction in one of his jokes[1] about the Big Bertha gun [1]. Certainly, this joke has found its path to the ISMD99 participants as it reflected worries about the future path of HEP towards an era dominated by a single laboratory. That was a time of big successes of the Tevatron and HERA experiments, yet thousands of physicists started to join the LHC, leaving few to continue other HEP projects, such as the future linear collider, second phases of the Tevatron and HERA experiments and the B-factory at SLAC. Even today the transition from the multi-lab HEP environment to a single-lab, single-reaction HEP concerns many as it jeopardizes diversity and viability of our field. But what is also true is that with the start of the LHC program now we have passed the uncertainty we had ten years ago. The LHC physics results will ultimately determine the future of the field, opening the doors to other HEP projects which will focus on detailed studies of glimpses of new physics which might be found at the LHC.

This path to this era has not been easy: Recently, we have been witnesses of many LHC problems; LHC experiments are still behind the schedule and the designed energies. But the very fact that, at this very early stage of the LHC project, we are overwhelmed with new results directly relevant to the main goal of this symposium - to understand the nature of strong forces through multiparticle final state is promising for the long-term health of HEP. Certainly, without understanding of soft QCD responsible for multihadron production, no progress can be made for future discoveries at high energies.

The current symposium marks three important events: We are celebrating 40th anniversary (the Roman number XL which was a source of various jokes, most of which referred to an extra-large meeting). This anniversary means that this symposium is one of the oldest HEP conferences. Secondly, we are celebrating first year of data taking by the LHC experiments, and talks from the ATLAS, ALICE, CMS and LHCb collaborations are a good snapshot of the LHC

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[1] In fact, it was a lament for the HEP physics as we knew it at that time, with multiple dwellings for particle colliders and diversity in studied collisions.

physics results from the first year of data taking. Finally, we are celebrating the retirement of E. De Wolf, whose "multiparticle physicist" career spans more than four decades, starting from the very first ISMD meeting, and who is presently the host of this meeting.

2 Multi-particle and multi-scientist dynamics at new energy frontier

The International Symposium on Multiparticle Dynamics (ISMD) has a long and well established history of expertise in so-called early-LHC measurements focusing on inclusive particle spectra and jet production. In particular, this includes single-particle spectra of charged particles and their short and long-range correlations, underlying events, hadronic-final state in diffraction, strangeness production, and various aspects of jet measurements (inclusive jets, inter-jet activity, multijets, etc.). During this meeting, all LHC experiments demonstrated their recognition of the fact that a main gateway to new physics is through understanding of strong forces responsible for multi-hadron and multi-jet production. This symposium is the forum with the largest attendance of experts in the field of multi-particle dynamics, bringing together theorists and experimentalists to discuss the major issues which are most important at this early stage of the LHC operation, such as QCD physics at the new energy frontier, mechanisms for particle production at highest pp-collision energies ever studied, interplay between soft and hard QCD, tests of particle-production models.

This meeting started forty years ago in 1970 in Paris, with the goal of understanding the description of inelastic collisions with several hadrons in a final state. Earlier, the main attention was concentrated on elastic collisions, but the presence of "background" inelastic events with several low-p_T hadrons in a final state became fairly sizable and difficult to ignore. There were very few theoretical models at that time. One of the popular descriptions was the longitudinal phase-space model by L. Van Hove, who was born not far from here - in Brussels. At that time, Polish and Russian groups were active in analysis of inelastic data. Therefore, the goal of that meeting was to setup a dedicated international conference to discuss multi-hadron production, alternating their location between East and West countries divided at that time by the Iron Curtain.

After forty years, we are talking about tens of thousands of produced hadrons, digital data recording and millions of observed W and Z bosons. Numbers of produced jets can be as high as the multiplicities of hadrons measured some twenty or thirty ears ago, so that one can apply similar statistical techniques to analyze multijets as those used for hadrons a few decades ago. Essentially, every aspect of this progress has been reported during this symposium.

Experimental research has become theory-driven as we are equipped with the Standard Model, which incorporates non-perturbative and perturbative QCD calculations, such as leading-order (LO), next-to-leading order (NLO), next-to-next-to leading order (NNLO), analytical perturbative QCD with its leading logarithmic approximation (LLA) and modified leading-log approximations (MLLA), and the local parton-hadron duality hypothesis (LPHD) to relate parton spectra with observed hadrons. Detailed Monte Carlo (MC) models also become available, embedding various phenomenological approaches for soft QCD and experimental data into a numerical simulation for generations of events on an event-by-event basis.

There is another side of this progress. During this meeting, many people attempted to fit new experimental data on the density of charged particles at mid rapidity in various collisions (see Fig. 1(left)). As an example, it was shown that the LHC data for charged-hadron pseudorapidity

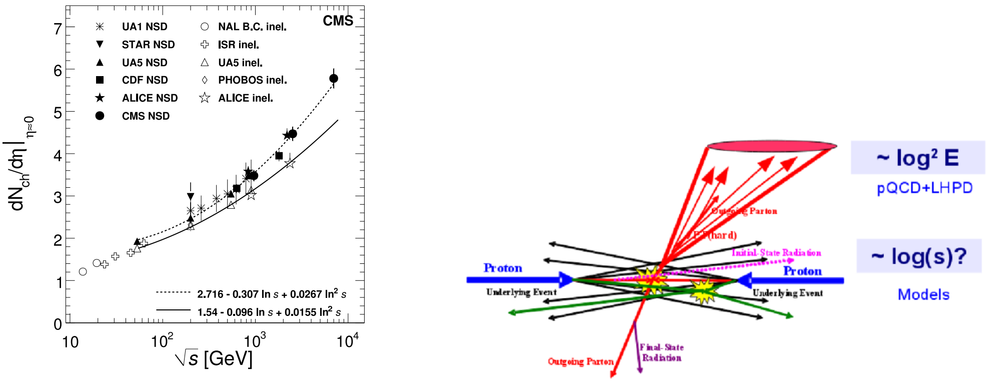


Figure 1: Left: particle density in mid rapidity and; Right: a sketch of two aspects in multi-particle production in *pp* collisions (based on the original figure by R. Field).

density lay exactly on a linear fit of AA data plotted as a function of the centre-of-mass energy rescaled using a simple assumption on quark interactions [2]. I have also made my modest contribution to this subject by estimating the number of scientists associated with experiments as a function of the center-of-mass energies. The density of charged particles per unit of rapidity increased from about 1.5 (30 GeV, ISR inelastic) to 4 (2.36 TeV, LHC) [3]. The number of analyzers has increased from roughly 20 (ISR) to 2000 (ATLAS or CMS), excluding the support personnel. So, unlike multiplicities (which follow an approximate logarithmic trend with the centre-of-mass energy) the increase in the number of physics is approximately proportional to the energy of colliding beams. The major question is: what technology can stop this trend before this field collapses into a single experiment focused on a particular aspect of high-energy collisions?

The LHC multi-scientist experiments have a second aspect: previously, only a few people (usually Ph.D. or Post.Doc.) were required to produce a "classical" experimental paper, similar to those papers published by the LHC experiments this year. Nowadays, a classical analysis on inclusive particle spectra requires an involvement of dozens of analyzers who are often scattered between multiple universities and time zones, without being attached to a host laboratory, only having remote communication and, finally, often having little chance to present their results at the major conferences such as this one. This last feature could be rather nasty for establishing careers of young scientists beyond the scope of their experiments, and the consequence of this effect needs to be seen in the future. Certainly, studies of multi-scientist dynamics in experimental HEP should also be at the center of attention.

3 Multiplicities and single-particle spectra

With increased center-of-mass energies at the LHC, we have entered regions with the smallest momentum fractions for produced partons, thus with the largest probability for multihadron production. This is already the case for jets with the highest transverse momenta ever observed, which are currently under intense scrutiny at the LHC. For the so-called minimum bias events, as they are typically defined by experiments, we are already on the front line with the unknown since the hadronic production of such events are determined by the energy of the colliding beams (Fig. 1(right)).

Results on the multiplicity distributions of charged particles shown in Fig. 2 from three LHC experiments [4–6] point to one common feature: all Monte Carlo generators fail to describe the data. It should be mentioned that most MC tunes were done using lower-energy data from the Tevatron, so that the failure of the MC generators is a sign of the same feature seen over and over in the past: Monte Carlo simulations only catch qualitative features once the experiments move to unexplored energies.

Indeed, Monte Carlo generators are never perfect after entering new energy frontiers: the same discrepancies have been observed earlier by LEP, HERA and Tevatron experiments after beginning of data taking. Only later work on MC tuning helped to reconcile data and MC, allowing one to proceed towards high-precision measurements. For example, one can find discrepancies between LEPTO and H1 measurements discovered after few years of HERA data taking [7].

In the past we said the same about analytical perturbative QCD calculations (see reviews [8]) which, in conjunction with the LPHD, catch the main trends of the data, but they fail on a quantitative level. Unlike the analytical QCD with few free parameters, we usually do not know exactly what is missing in MC simulations, but we know that such generators can be tuned given many free parameters (for example, there are about a dozen parameters used for the description of multiplicities in the underlying event of pp collisions).

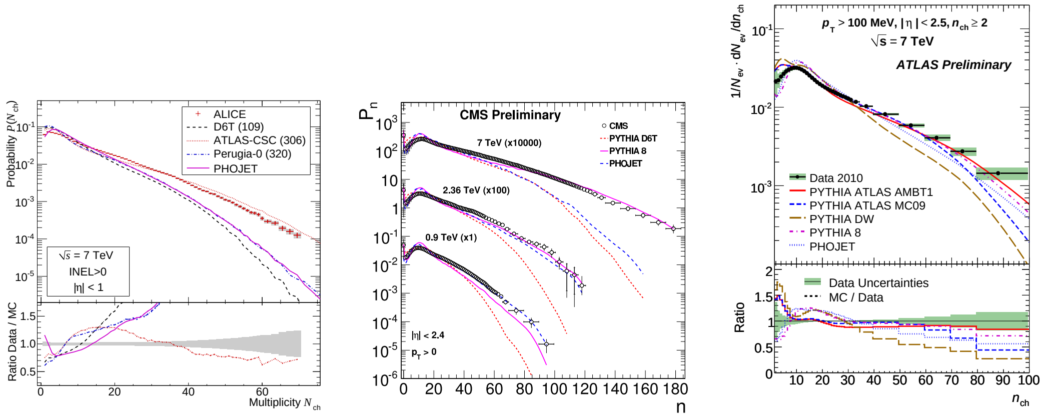


Figure 2: Multiplicity measurements from three LHC experiments (ALICE, CMS and ATLAS, from left to right). All plots feature discrepancies between MC tunes and the data.

Let us move on to single-particle spectra, i.e. from the question of the frequency of particle appearance to the question of how particles populate phase space. Generally, the shapes of the density distributions in pseudorapidity and p_T are well described by the models. However, ATLAS reported a significant reduction of the average p_T as a function of the number of charged particles compared to the existing MC simulations, indicating that the particle spectrum is softer than expected, see Fig. 3.

It is interesting to observe that different experiments have chosen somewhat different but complimentary approaches for studies of the particle spectra: ATLAS mostly focused on comparisons of data with different MC tunes (which all show discrepancies with the measurements), while CMS gravitated towards comparisons with other experiments and fitting the data using analytical parameterizations.

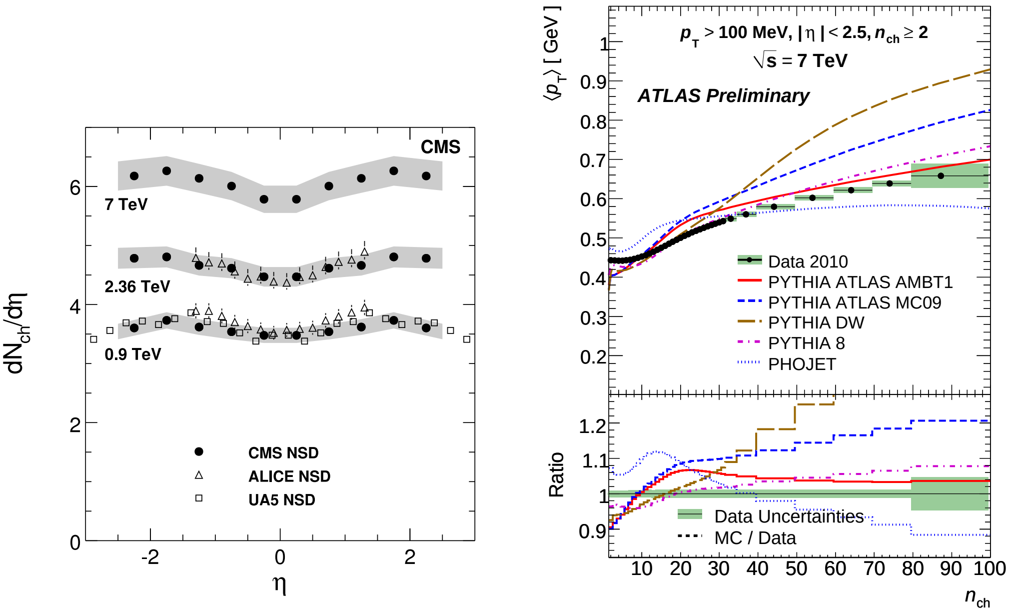


Figure 3: Distribution of charged particles in η (CMS) and the average transverse momenta of charged particles as a function of multiplicity (ATLAS). The later plot shows significant discrepancies with the data.

Another area where all MC fail to describe the data is strangeness production, which is a QCD aspect largely determined by the fragmentation process. In this area of soft QCD, the situation is nothing but a disaster. The MC expectations indicate too low rate of strange particles, see Figs. 4, 5 and 6. This also reminds us of early HERA measurements, where the production rates of K_0^S and Λ indicated that the value of the strangeness-suppression parameter previously tuned using e^+e^- data seemed inadequate for ep collisions. The recent HERA paper [9] reported that the Lund string model with a single suppression parameter λ_s fails to describe details of the K_0 and Λ production in various regions of phase space, in particular, for low p_T and low x regions.

For baryon production, the only measurement for which the MC description does not fail was $p/\bar{p}$ ratio measured by LHCb [10], see Fig. 6. Interestingly enough, a good agreement for this ratio was reported for the Perugia0 tune, which is known to fail for inclusive multiplicity measurements (although, $p/\bar{p}$ can be rather insensitive to inclusive particle spectra).

Many physics processes to be studied at the LHC require precision measurements of jets and missing transverse energy. An important and unavoidable background for these measurements comes from the so-called underlying event, which represents the soft part of the proton-proton interaction and which must be modeled using Monte Carlo generators. Such models should be tuned to experimental data before any high-precision measurement can take place. Typically,

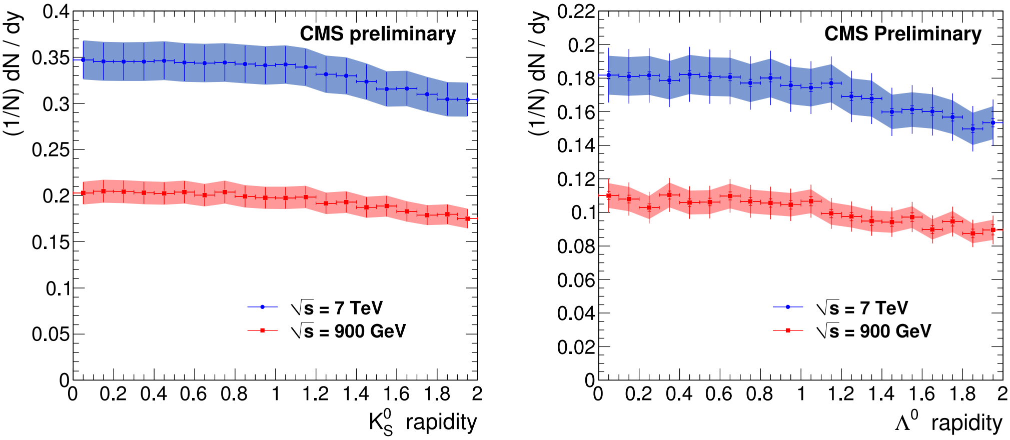


Figure 4: CMS results on strangeness production.

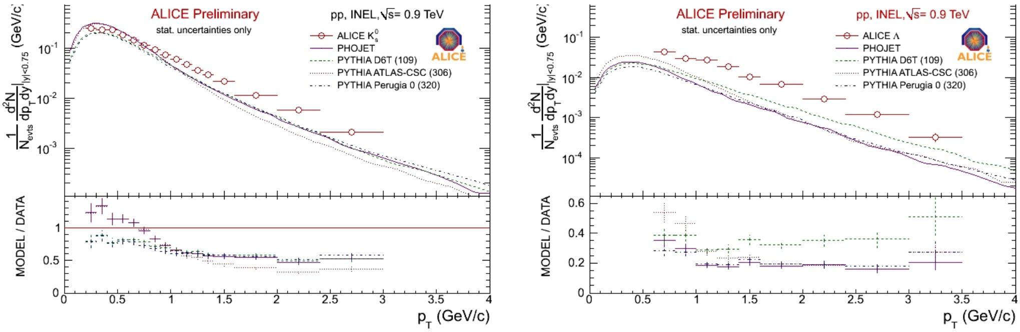


Figure 5: Results on strangeness production by the ALICE experiment.

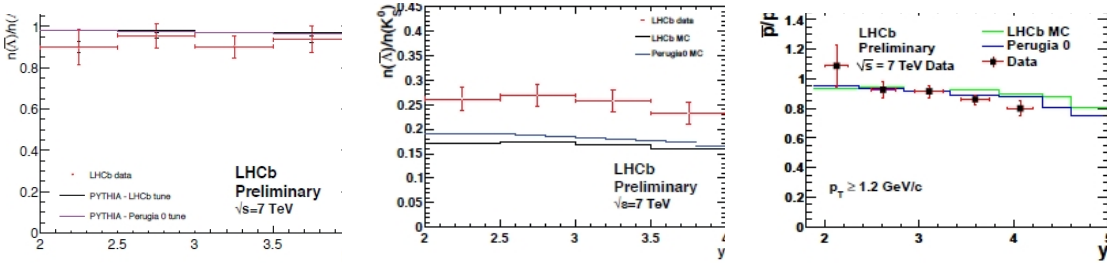


Figure 6: A snapshot of the LHCb results on strangeness production.

the underlying-event measurements focus on the "transverse" region, i.e. on the region perpendicular to the direction of a hard jet. This region is considered to be the most affected by soft QCD processes, so that the density of particles in this region is almost independent of the hard interaction (but depends on the CM energy). Not surprisingly, both ATLAS and CMS [5, 11] have found that the MC simulation needs to be re-tuned to reflect a high density of particles in the transverse region.

Figure 7 shows the ATLAS results on particle densities in the transverse region when the direction of hard interaction is approximated by a leading p_T track. Unlike this approach, CMS reconstructed the transverse region using leading jets. Both results indicate differences between the data and the MC simulations.

During this meeting, Rick Field has shown that one can archive a reasonable description of the data using the so-called Z1 tune. Unfortunately, it was difficult to reconcile this tune with lower-energy CDF data. One possible option discussed during this meeting is to introduce an energy-dependent parameter for the description of the underlying event. It is not easy to decide which parameters need to be modified: there are a dozen parameters in PYTHIA that determine the density of particles in the underlying event. It is almost guaranteed that they are not fully independent, which introduces a certain unambiguity in the description of the underlying event.

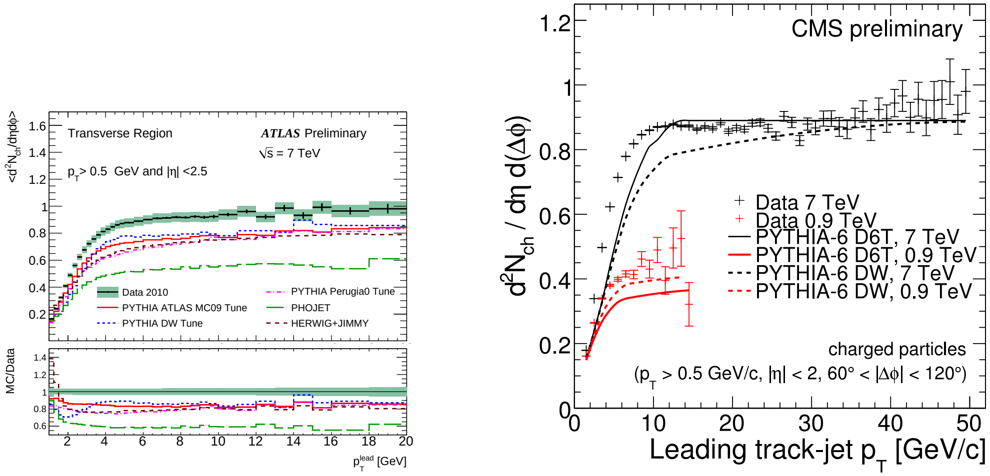


Figure 7: Underlying event measurements by ATLAS and CMS. The collaborations used two different approaches to identify the transverse regions: ATLAS used leading tracks, while CMS uses leading jets. Both results indicate the same feature: the MC needs to tuned to describe the density of particles in the transverse region.

One hope to understand the underlying event in *pp* is to isolate different bits of the physics contributing to it. For example, HERA data provide a clean environment in which multiparton interactions (MI) can be studied without other processes which typically contribute to what we call the "underlying event" in *pp* collisions. The HERA measurements [12] support the presence of multiparton interactions, but the statement on their size is not yet conclusive; while the H1 measurement does require the PYTHIA model with MI included, the fraction of such events depends significantly on the choice of factorization scheme for the description of the parton-shower mechanism.

Diffraction is another piece of the puzzle. It is generally accepted that diffractive events are not a major contributor to the underlying-event measurements at large p_T. Uncertainties on the strength of hard diffraction are still present, and this has to be solved. Recent attempts to include a hard diffractive component to the new PYTHIA8 model is one step towards a better description of the LHC data. The measurement of observables sensitive to diffraction, such as the traditional $\sum(E + p_z)$, is important by itself. First CMS [5] results on direct measurements clearly indicate the presence of diffraction. Interestingly enough, the measurements are reasonably described by the PHOJET simulation, see Fig. 7(right).

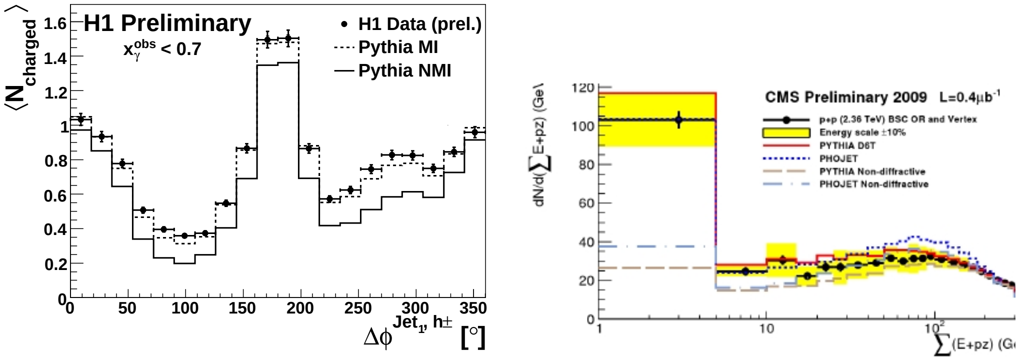


Figure 8: Studies of multiparton interactions by H1 (left figure) and measurements of diffractive events at the LHC (right figure).

Forward jet physics has received a lot of attention by all LHC experiments. Both ATLAS and CMS have four detectors each to measure energy deposits up to 13 units in pseudorapidity. ALICE comes close with three detectors dedicated to forward region. The LHCf experiment successfully took data which will be analyzed to provide unique information on energy showers which can be used for simulation of extensive air showers in cosmic rays up to 10^{15} eV. This appears to be close to the energy range (10^{18} eV) of high-energy cosmic rays observed at the Pierre Auger Observatory and the HiRes experiment.

There were several presentations by CMS and ATLAS on forward physics. The CMS experiment studied “energy” flows up to five units in pseudorapidity, while ATLAS concentrated on track densities [13]. The conclusion from these studies was somewhat confusing: CMS reported that all MC tunes fail, but PYTHIA D6T is closest to the data, while ATLAS has found that PHOJET describes the data reasonably well. As was mentioned earlier, PHOJET fails to describe the UE measurements.

4 Beyond single-particle densities

The CMS collaboration [14] spearheaded correlation studies right after a few first months of the LHC data taking, way ahead of the other LHC experiments. This is partially related to the fact that they started to explore low-p_T tracks earlier than other experiments (in particular, ATLAS). Two-particle short-range correlations in η and ϕ have been studied using the tradi-

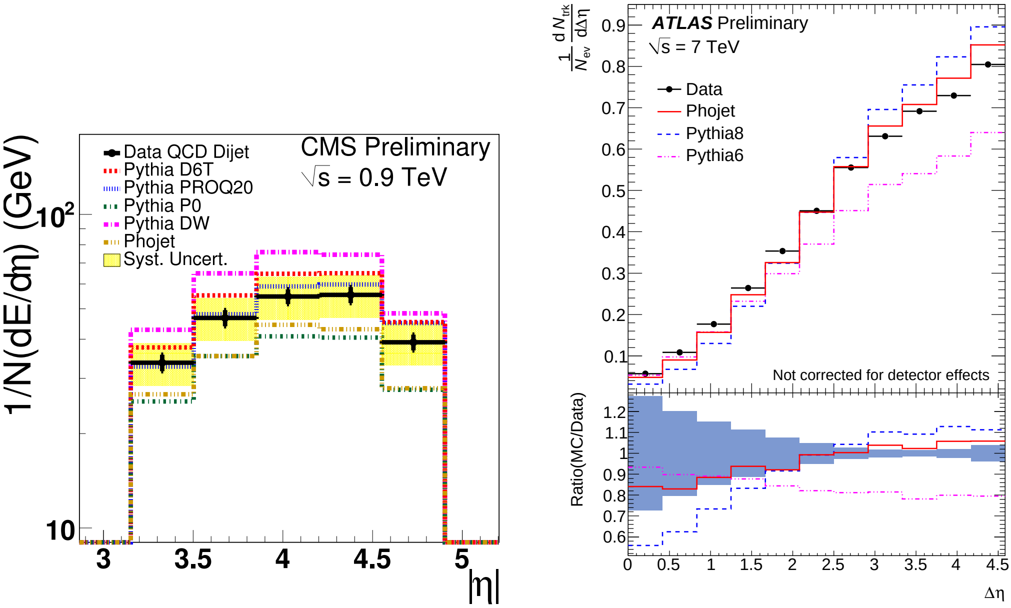


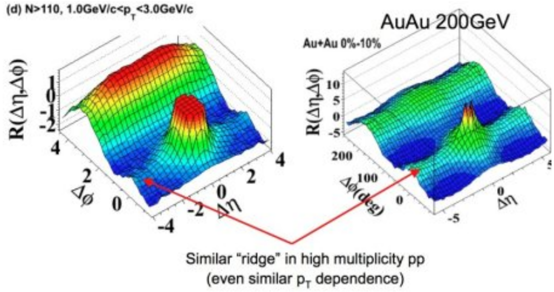
Figure 9: Studies of forward physics by CMS and ATLAS.

tional approach of dividing the two-particle densities in $\eta - \phi$ phase space by similar densities using a track-mixing technique (when two tracks are taken from different events). Such short-range correlations are reasonably well described by a Gaussian; such a description allowed the determination of the cluster sizes using the classical model of Eggert et al. [15].

A sudden surprise came in the middle of the symposium. CMS reported [14] an observation of long-range correlations similar to those found in AA collisions. This became possible after looking at high-multiplicity events triggered using a dedicated trigger, and concentrating on a low-statistics region away from the main peak caused by short-range correlations. Figure 10 shows the so-called ridge structure, an effect which was observed in heavy-ion collisions. The effect implies that there are positive long-range correlations in η for tracks with similar azimuthal angles. If the effect is confirmed by other experiments, this will indicate that there is interesting physics which is currently missing in our understanding of pp interaction (it is certainly missed in the Monte Carlo simulations). It should be noted that the effect is tiny, compared to short-range correlations (i.e. the height of the peak at zero), and thus it could have been overlooked. As an example, the dA reaction [16] does not show this structure, albeit the measurement was performed with significantly lower statistics than those presented by CMS.

From the same category of effects, when simple collisions have a signature of AA collision, is an observation of excess of deuterons produced in ep collisions, which is difficult to interpret in terms of the standard fragmentation and coalescence of neutrons and protons [17].

Bose-Einstein (BE) studies at the LHC were first published by CMS [18] and during this meeting such studies were also presented by ALICE [19], see Fig. 11. One should note the precisions with which the measurements have been done: the BE signal is clearly seen and is well described by an exponential. It should be noted that only 20 years ago, many collabora-



Similar "ridge" in high multiplicity pp
(even similar p_T dependence)

Figure 10: Long-range correlations observed by the CMS collaboration and an example of similar correlation in heavy-ion collisions (AuAu collisions at 200 GeV).

tions were rather uncertain about the shape of the Bose-Einstein effects; now, after few months of data taking, data unambiguously disfavor the classical Gaussian shape. As shown by ALICE, the radii of BE correlations depend on multiplicity, thus confirming earlier measurements (Fig. 11(right)). Further notable progress was reported by the L3 experiment [20]: it was shown that a dip near 0.5 units in Q_{12} can well be described by the τ-model. This feature was also apparent in ep collisions [21], but no clear interpretation was attributed at the time when that measurement was performed.

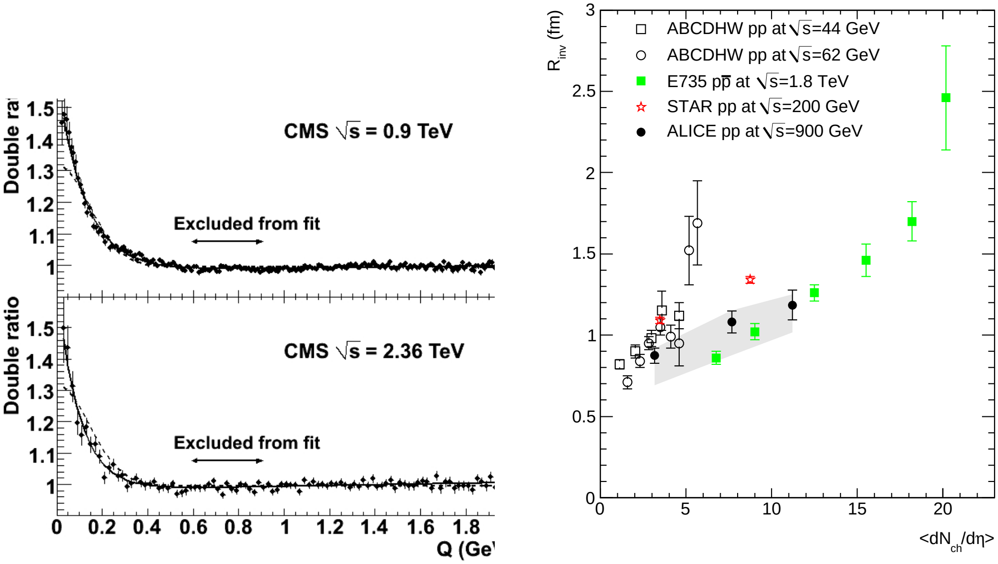


Figure 11: BE correlations measured by the CMS (left) and by ALICE (right) experiments.

5 High p_T electroweak and QCD physics

As for the previous ISMD conferences, a lot of attention was paid to high-p_T electroweak physics [22] and QCD-jets. Both ATLAS and CMS have reported the measurements of Z and W cross sections, comparing them with NNLO predictions, see Fig. 12 and 13. With the present statistics, no deviations have been observed from the NNLO calculations.

With the advent of the LHC data taking, jet physics becomes an important part of QCD studies at the new energy frontier. With only 10 pb^{-1}, the reach in jet transverse momentum at the LHC will be twice that attained by previous experiments. The LHC is not there yet, but the very first results from ATLAS and CMS [23] are a good indication that we are on the right path (see Fig. 14).

Jet physics is also an important part of the program for searches of new physics. One promising path to discoveries at the LHC is through studies of jet substructure: heavy particles with masses close to the TeV scale can decay into states which undergo a significant Lorentz boost. This leads to partial or complete overlap of their decay products which cannot be reconstructed as separate objects. In this case, jet-shape characteristics can be useful in reduction of the overwhelming rate of conventional QCD jets and can open the path to a direct observation of new states. Both ATLAS and CMS have made first steps towards understanding jet shapes as shown in Fig. 15. Unfortunately, there is not much coordination between CMS and ATLAS in their jet studies: CMS uses the anti-k_T jet cone sizes 0.5 and 0.7, while ATLAS uses the cone sizes 0.4 and 0.6. This prevents a direct comparison of the jet cross sections measured by the experiments.

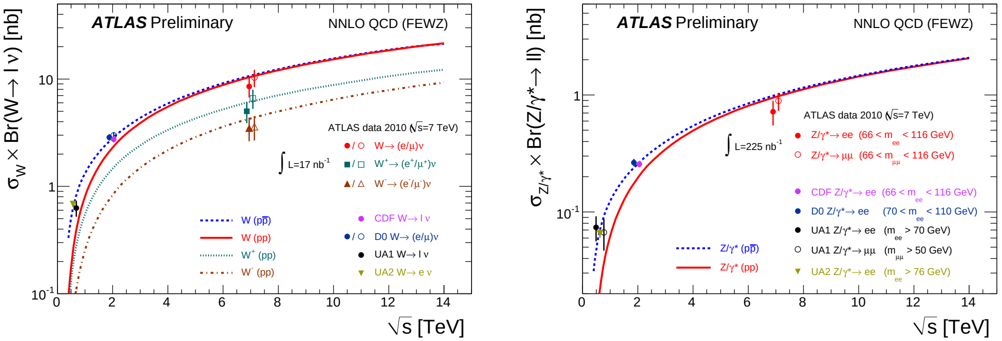


Figure 12: The ATLAS cross-section measurements of W and Z compared to the NNLO calculations.

Both CMS and ATLAS have reported the measurements on model-independent searches for bumps in invariant masses of dijets, see Fig. 16. No excess was observed. The results extend the reach of previous Tevatron experiments by almost 500 GeV.

One should note that exotic physics may exhibit itself through a production of final states consisting of multiple objects (leptons, jets etc.) at relatively low p_T. As an example, one expects decays with copious lepton (slepton) production in LeptoSusy models. For such processes, techniques developed for the description of multihadron production can be extremely useful.

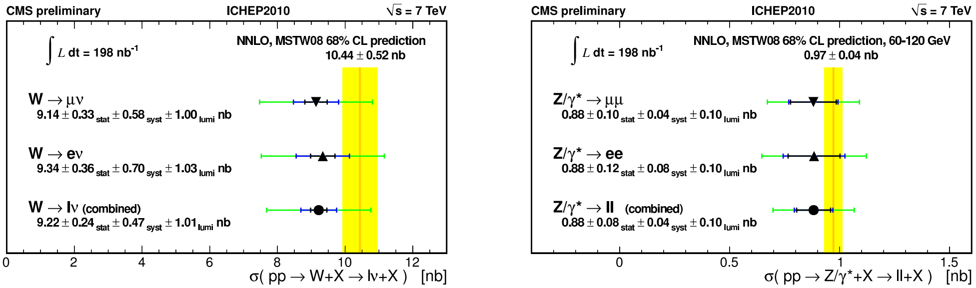


Figure 13: The CMS cross-section measurements of W and Z compared to the NNLO calculations.

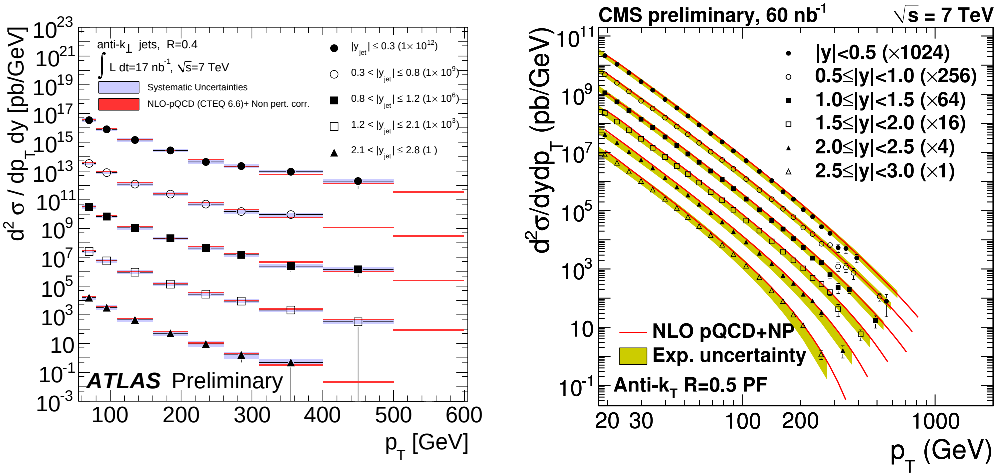


Figure 14: Inclusive jet cross sections compared with the NLO QCD predictions presented by the ATLAS and CMS Collaborations.

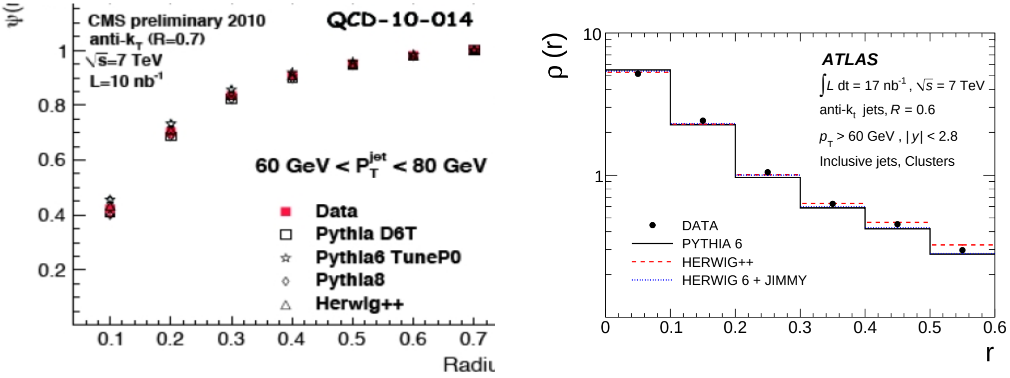


Figure 15: Differential and integral jet shapes reconstructed by CMS and ATLAS.

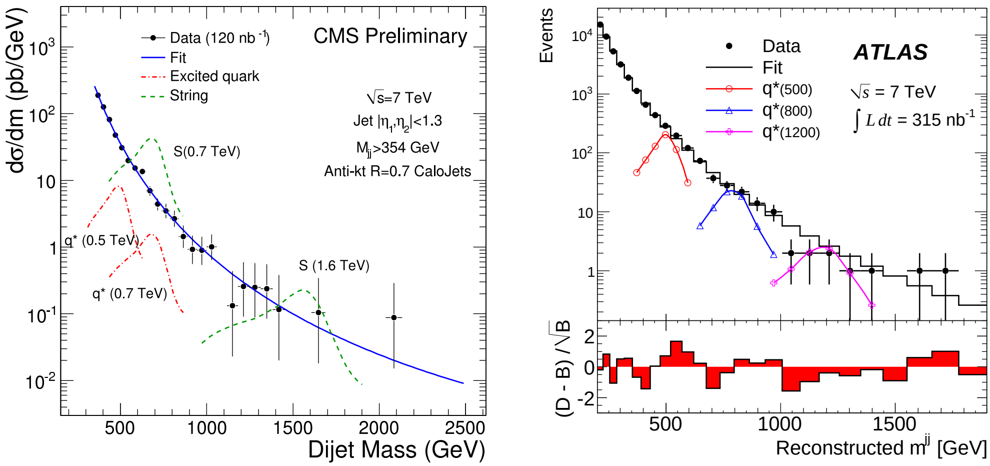


Figure 16: Invariant masses of dijets reconstructed by CMS (left figure) and ATLAS (right figure).

6 From young to mature

During this meeting, we spoke about HERA results, rather than H1 and ZEUS results separately. HERA provides very precise information on proton structure functions over a wide range of Q^2 and x after combining ZEUS and H1 measurements. The combination of results is done using elaborate experimental techniques, which represents a significant value for the current and future twin experiments. Figure 17 shows combined ZEUS and H1 results on the F_2 measurements [24]. Currently, the determination of parton density functions using combined HERA results lead to $\sim 2-3\%$ uncertainty on W measurements at the LHC. This can be compared to a 5% uncertainty for a separate H1 or ZEUS determination. As mentioned before, HERA provides the world's most precise measurements of Pomeron structure function (not yet combined, but this task in the pipeline), F_2^{cc}, F_2^{bb}, F_L, data on jets and observables which are directly sensitive to multiparton interactions. During this meeting, it was illustrated that the current precision on F_2^{cc} is sufficient to observe differences between different structure functions, something which was impossible a few years ago due to luck of statistics.

It should be noted that the next challenge in exploring the parton densities is to study regions of low-x ($< 10^{-3}$) and high Q^2 ($Q^2 > 100$ GeV). The LHCb program can certainly help in tackling this issue. Due to its angular acceptance and low trigger thresholds, events at LHCb will probe a totally unexplored kinematic region using W and Z bosons. In particular, the LHCb will have access to low-x at high Q^2.

The Tevatron is no longer the highest-energy baryon collider after the LHC started its operation with 7 TeV beams. But high-statistics, high-precision, well-understood Tevatron experiments are a critical component in searches in decay channels which are difficult to measure at the LHC, such as light Higgs which is more likely to decay into pairs of b-quarks. Because of this, the Tevatron is still a competitor to the LHC for some discovery channels, and it still provides reference QCD measurements for early LHC results [25].

The study of ultra-relativistic heavy ion collisions already has a history of 30 years with

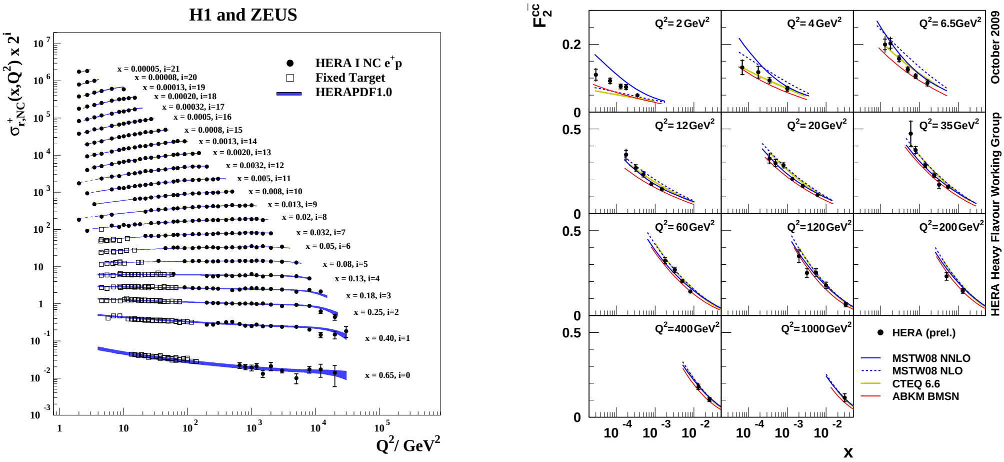


Figure 17: HERA measurements of F_2 and $F_2^{c\bar{c}}$.

experiments spanning a large range of energies from the AGS accelerator at BNL (5 GeV/c), the CERN heavy ion beams at the SPS accelerator (17 GeV/c) and finally the Relativistic Heavy ion Collider (RHIC) at BNL where the energies reach 200 GeV. One of the strongest motivations in the past was to search for the quark-gluon plasma. This motivation can already be found in this short paragraph written 30 years ago by J.D. Bjorken in his (unpublished) preprint: *For pp collisions with high associated multiplicity and with transverse energy 10 GeV per unit rapidity, it is possible that quark-gluon plasma is produced ... If so, a produced secondary high-*p_T *quark or gluon might lose tens of GeV of its initial transverse momentum while plowing through quark-gluon plasma in its local environment.* It is remarkable that was said about *pp* collisions, which is a good plea for similar studies at the LHC experiments.

After 30 years and the first decade of the RHIC running, PHENIX is close to producing a complete picture of energy losses using identified particles and jets. Essentially, every single channel that PHENIX [26] studied had an indication of strong suppression of production rates compared to *pp* collisions. There are many other interesting topics, such as η' mass reduction, correlation studies, various test of hydrodynamics description of particle production, all are quite relevant for high-multiplicity *pp* events and the future of the heavy-ion LHC program.

BaBar, Belle and CLEO remain as flagships of particle spectroscopy, but when it comes to $Y(3S)$, BaBar [27] is certainly a winner after accumulation of worlds largest sample of $(3S)$ in 2008 (120 M events). Precise measurements shown during this meeting provided a good snapshot of what can be done with such enormous statistics.

7 Failed illusions or illusion of failures?

Before going to my summary, let me again elaborate on the MC comparisons with the early LHC data, given importance of this topic for the LHC and for this meeting.

During this symposium, unlike at any other in the past, we have seen many MC failures to describe data. These MC simulations have been used for various physics performance studies

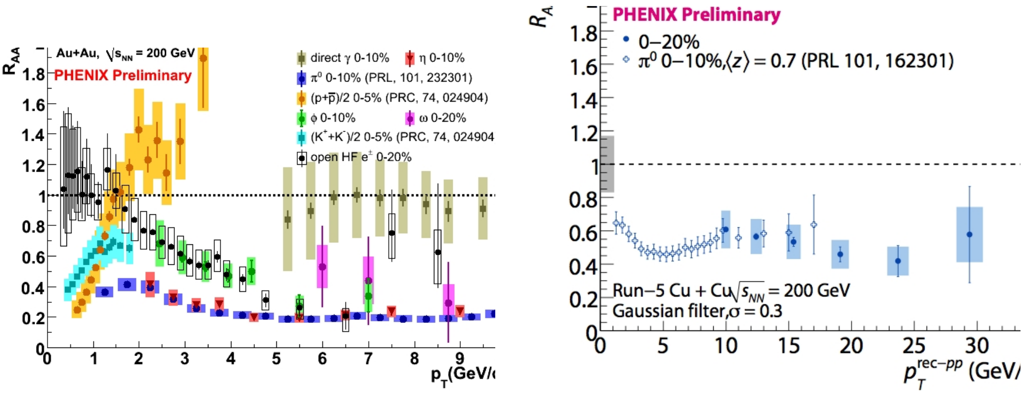


Figure 18: Energy loss measurements using identified particles and jets.

in the past, and many key LHC progress reports were relied heavily on such models. Maybe we had overly high expectations for MC generator at that time?

For years, we have believed that all major pieces of physics are included in the MC generators. Given the complexity of the description of soft QCD and hadron production with multiple contributions from many physics processes, and often due to the lack of knowledge on their strength, the MC had to be tuned to data. This leads to a certain illusion that MC can explain the data while, for most inclusive particle spectra, they are just a method of reproducing inclusive data in a convenient way. This means they lack predictive power which is typically required from a theory. The consequence of this was demonstrated by this symposium: Tuned to lower-energy data, MC fail once we go to a high energy. Being tuned to the new high-energy data, they fail in the description of lower-energy data or other reactions. And even for a given energy, there are tensions for the description of different observables. I'm sure the Monte Carlo generators will be tuned again to describe the new data, although this unlikely will solve the central question of understanding soft QCD.

I think we will be less confused about MC failures considering these models merely as a way to embed inclusive particle spectra into a theoretically-motivated fit every time we enter new energies. It is a handy and essential tool for performing experimental measurements (detector unfolding) and archiving data[2] in a convenient way for background studies for better isolated and better understood electroweak processes.

Some theorists may say: MC generators do qualitatively describe the data, but they fail in details. I have found this argument weak: many theoretical calculations describe data qualitatively with only a few parameters, but fail on a quantitative level. Then, the main question is this: beyond which point should we claim that the number of free parameters is justifiable for a given degree of quantitative agreement and for claiming that we can explain data. I would forward this question to theorists.

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[2] By this I mean that experimental data can be recreated on the fly by a piece of code, instead of storing each event using data storage.

8 Summary

This meeting was a major milestone on our road to understanding multihadron production and soft QCD. The LHC experiments are dominant players, but do not forget other successful ongoing experiments the legacy of which will remain with us for the indefinite future. Experimental results from the LHC and high-precision measurements from HERA, RHIC, LEP, BaBar and Tevatron discussed at this symposium is a good snapshot of our progress in the understanding of multiparticle production.

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