Intermittency in pp collisions at $\sqrt{s} = 0.9$, 7 and 8 TeV from the CMS collaboration

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Abstract

In an extension to our previous work where we established that the intermittency-type fluctuations as outlined by Bialas and Peschanski in the 1980s is present at $\sqrt{s} = 7$ TeV, the analysis is continued to include more energies from Run 1 data from the CMS collaboration at CERN. A preliminary look into how the slope parameters in the bin-averaged scaled factorial moments vary with collision energy at the TeV scale is presented, and we outline possible areas planned for future studies.

Introduction

Intermittency in multiparticle production, where fluctuations in particle multiplicity can be observed at all scales, can be quantified via the bin-averaged scaled factorial moments [2, 3]:

$$F_q(\delta\eta) = M^{q-1} \sum_{m=1}^{M} \frac{\langle n_m(n_m-1)\dots(n_m-q+1)\rangle}{\langle N\rangle^q} \tag{1}$$

where F_q is the q^{th} bin-averaged moment, M is the number of bins that the (pseudo)rapidity space is divided into (each with size $\delta\eta$), n_m is the multiplicity in bin m, N is the total event multiplicity and $\langle\dots\rangle$ represents an average over events. Equation (1) is sometimes known as the "horizontal moments" in intermittency literature.

In Bialas and Peschanski's formulation [2, 3], a system is said to be intermittent if a power-law relation exists between F and $\delta\eta$,

$$F_q \sim (\delta\eta)^{-f_q} \tag{2}$$

and we expect an intermittent system to produce a straight line in a $\ln F_q$ vs $\ln(1/\delta\eta)$ plot towards $\delta\eta \to 0$, with some positive gradient f_q called the "slope parameter" or "intermittency exponent".

Motivation and Objectives

With the LHC at CERN ushering in a new era of TeV-scale high energy physics, it is worthwhile to reinvestigate this phenomenon in a new energy regime. In our previous work [8], we found that intermittent phenomenon exists in pp collisions at $\sqrt{s} = 7$ TeV. That motivates our current investigation, where the analysis is extended to include the other available energies in Run 1 from the CERN Open Data Portal – 0.9 and 8 TeV from the CMS collaboration. Hence we aim to:

1. Compute the bin-averaged scaled factorial moments and produce log-log plots of F_q vs $(1/\delta\eta)$ for pp-collisions in $\sqrt{s} = 0.9$, 7 and 8 TeV data from the CERN Open Data Portal.
2. Obtain the intermittency exponents for q = 2, 3, 4 and 5 for the data and make observations about any trends that appear.

Data Processing

MinimumBias datasets from the CERN Open Data Portal are used for this analysis – 900 GeV data from the Commissioning run of 2010 [6], 7 TeV data from RunA of 2010 [5] and 8 TeV data from RunB of 2012 [4]. About 500,000 events for each energy were skimmed using `CMSSW_4_2_8` (for 900 GeV and 7 TeV) and `CMSSW_5_3_32` (for 8 TeV) and processed using `ROOT`.

Event Selection

Vertices are required to have number of degrees of freedom (ndof) greater than 4, and be within 10 cm of the beamspot in the z-direction. If more than one primary vertex is present, the one with the highest number of associated tracks is chosen to be the primary vertex.

To remove secondaries from background and pileup, tracks are required to have impact parameter significances d_0/σ_{d_0} and d_z/σ_{d_z} to be smaller than 3. The relative uncertainty in the momentum measurement σ_{p_T}/p_T is required to be less than 5%. To ensure good reconstruction efficiency, only tracks carrying the `highPurity` flag and with $p_T > 0.5$ GeV are selected.

Results

Figures 1-3 show the log-log plots in F_q vs $(1/\delta\eta)$ for $\sqrt{s} = 0.9$, 7 and 8 TeV with error bars plotted (most are too small to be seen). Table 1 summarises the intermittency exponents, which are obtained via linear regression on the rightmost 10 data points of each set of data.

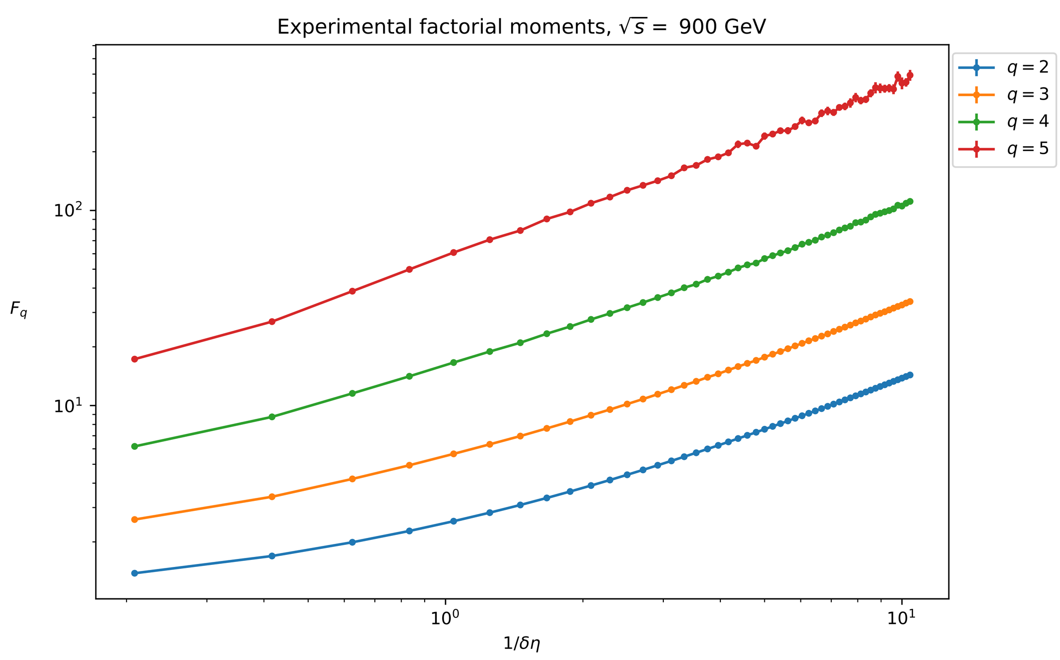

Figure 1: F_q vs. $1/\delta\eta$ for $\sqrt{s} = 0.9$ TeV

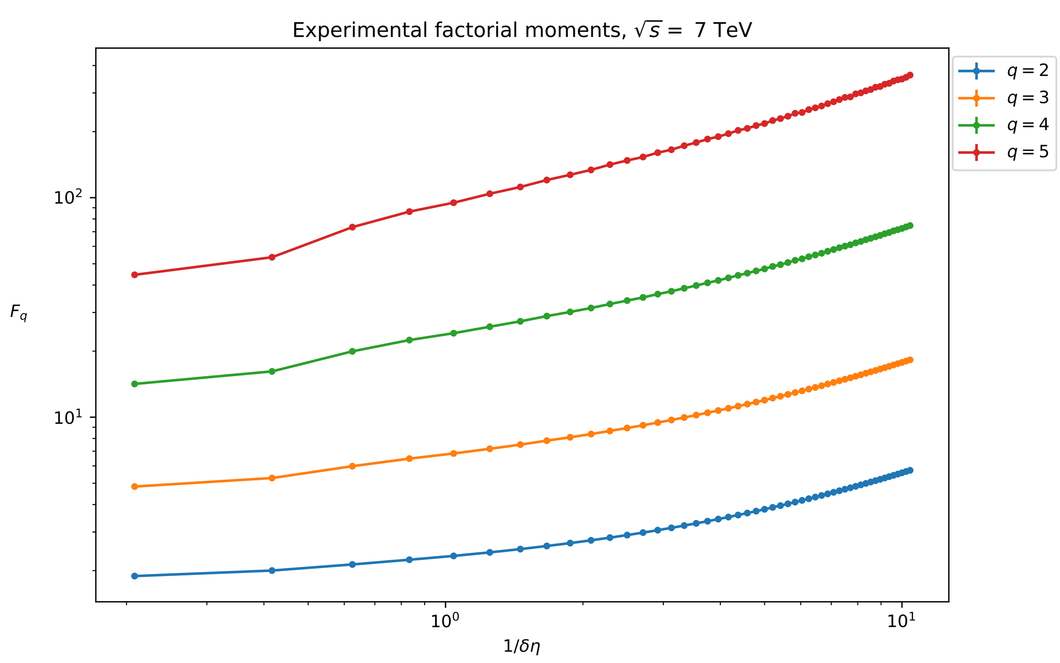

Figure 2: F_q vs. $1/\delta\eta$ for $\sqrt{s} = 7$ TeV

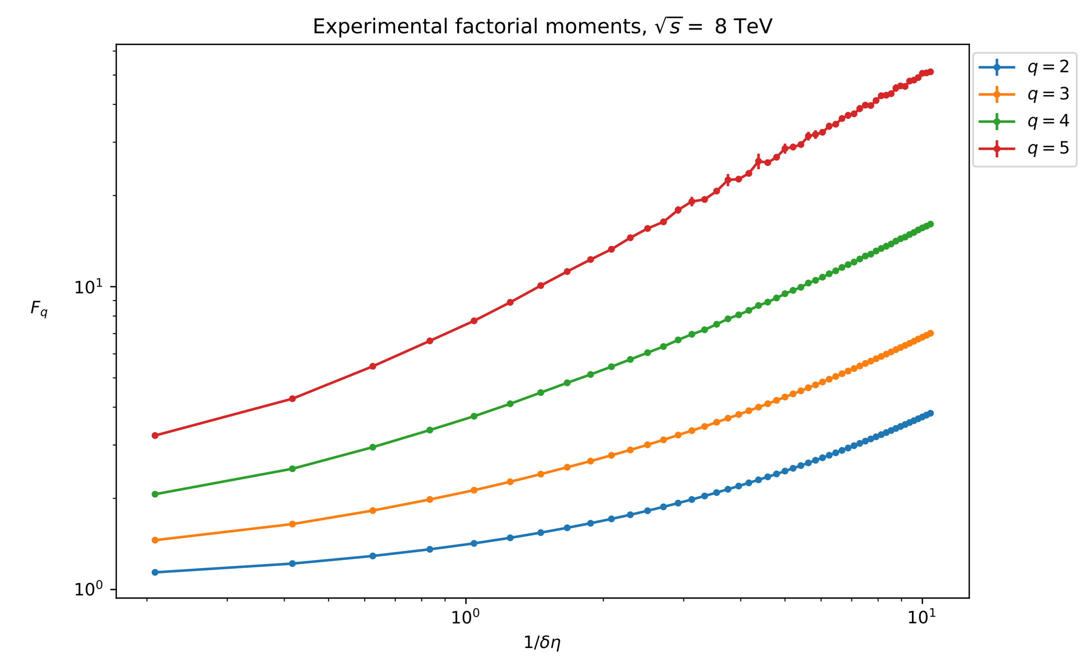

Figure 3: F_q vs. $1/\delta\eta$ for $\sqrt{s} = 8$ TeV

q	0.9 TeV	7 TeV	8 TeV
2	0.900 ± 0.001	0.620 ± 0.002	0.660 ± 0.002
3	0.913 ± 0.008	0.635 ± 0.002	0.712 ± 0.003
4	0.89 ± 0.05	0.669 ± 0.005	0.756 ± 0.009
5	0.8 ± 0.2	0.73 ± 0.02	0.82 ± 0.05

Table 1: Summary of intermittency exponents

Conclusion and Discussion

From the non-zero values in Table 1, we can immediately conclude that intermittency still persists in pp collisions up to $\sqrt{s} = 8$ TeV.

The intermittency exponents appear to decrease significantly from $\sqrt{s} = 900$ GeV to 7 TeV, before increasing slightly between $\sqrt{s} = 7$ TeV and 8 TeV. This finding is made with data treatment kept uniform across all three energies, which was challenging to do in previous studies.

Scaling, Universality and Branching

The results clearly show that the scaling relation of Equation (2) still holds at the energies being investigated. However, universality, as noted by Bialas [1] where the intermittency exponents are the same in all experiments, does not seem to hold. More analysis needs to be done before further conclusions can be made on this.

The concept of intermittency is closely related to parton branching processes in multiparticle production [1]. Our conclusion leads us to surmise that as the centre-of-mass energy increases into the TeV scale (especially based on the notable decrease from 0.9 to 7 TeV), other competing processes in multiparticle production might become increasingly important. Still, parton branching ideas remain valid and are a present area of study (see for example, [7]).

Forthcoming Research

This analysis can be further extended in the following areas:

1. **Unfolding (corrections)**: In this analysis, the particle multiplicities are derived by counting charged tracks from the tracker in CMS. The multiplicity distributions need to be unfolded back to the charged hadron level, so that we can study the intermittency effects from a QCD perspective. Unfolding will also correct for detector-related inefficiencies.
2. **Higher energies**: With the expected release of Run 2 data to the public, we can look forward to extending this study up to $\sqrt{s} = 13$ TeV, which will shed more light into intermittent behaviour at the TeV scale.

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