# Chou-Yang Model for Forward-Backward Multiplicity Correlations at 7 TeV using Generalized Multiplicity Distribution.

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**Abstract.** The basis of the Chou-Yang model is made up of a stochastic and non-stochastic distribution and has been successful in describing forward-backward multiplicities.[1] This project examines data drawn from CERN's 7 TeV run where we revist the Chou-Yang model's components. It also approaches phenomenological descriptions for cluster sizes from forward-backward multiplicaity correlation strength by the E735 collaboration.[6] For the stochastic binomial component, it examines the variance of the charge asymmetry parameter $z$ with regards to fixed total charged multiplicities $n$. The fitting of the Generalized Multiplicity distribution along with the linear least square fitting of the forward backward multiplicity is analysed. The parameters for the Generalized Multiplicity Distribution is presented along with an investigation on the cluster size $r$.[3] This serves as an extention to the work done by W.Y Wang's Weighted GMD model at 7 TeV, however the nonweighted GMD model is used here.[7]

## 1 Introduction

The basis of the Chou-Yang model is made up of a stochastic and non-stochastic distribution and has been successful in describing forward-backward multiplicities.[1] This project applies this model to CERN's 7 TeV data along with phenomenological descriptions of cluster sizes from the forward-backward multiplicity correlation strength [2]. The stoachastic component is made up of the variance of the charge asymmetry parameter $z$. The non-stochastic component involves the total charged multiplicity distribution, in the form of either the Negative Binomial Distribution(NBD) or the Generalized Multiplicity Distribution(GMD). These are then used to predict forward-backward multiplicity correlation and serves as an extention to the work done by W.Y Wang's Weighted GMD model at 7 TeV, although the non-weighted GMD model is used here.[3]

## 2 Chou-Yang Model

As of yet, there have been no successful attempts in explaining the mechanics of forward-backward multiplicity distributions. As a result, the Chou-Yang model is a phenomenological attempt at describing the forward-backward multiplicity distributions.[1] It is motivated by the observation that the distribution with respect to the charge asymmetry parameter, $z$ is binomial in nature where $z = n_f - n_b$, where $n_f$ and $n_b$ are the forward and backward charged multiplicities and the total charged multiplicity is $n$. It was found that the spectra of multiplicity distribution fits very well with the simple formula for 540 GeV.

### 2.1 Alterations to Cluster size

For a pure cluster model where each cluster is assumed to fragment on average into k charged particles plus neutrals, the binomial factor must be augmented to be $C^{n/k}_{(n+z)/2k}$ and therefore, $\langle z^2 \rangle = kn$.[4] The conclusion drawn in the previous section is that $k = 2$. However, there is no reason a priori that the cluster size should be independent of energy. Indeed, it was shown by Lim *etal* that there is indeed an energy dependence of the cluster size.[5][6]

The cluster size can be found through the proposed relationship between the $\langle z^2 \rangle$ at fixed $n$:

$$\langle z^2 \rangle \ at \ fixed \ n = kn \tag{1}$$

## 3 Generalized Multiplicity Distribution

Multiplicity distributions are interesting to analyse because they reveal useful information about particle production processes, for example, the shape of the multiplicity distribution will show whether the production of particles is correlated. The most widely accepted multiplicity distribution comes from the NBD, which assumes an initial number of ancestor particles which evolves to a final state of particles which are then detected.[3]

Similarly, the GMD is derived from the same idea of initial state to final state process. The GMD is derived as a solution to the stochastic branching equation which describes the evolution of quarks and gluons, formulated as a Markov branching process.[7] Given an initial number of quarks (q) and gluons (g) and assuming that the process of quark bremsstrahlung ($q \to q + g$) and gluon fission ($g \to g + g$) dominate. These two processes result in a shower of quark and gluons that hadronise into the final state particles which hit the detector. The stochastic branching equation is given as:

$$\frac{\partial P_{m,n}}{\partial t} = \tilde{A}mP_{m,n}(t) + \tilde{A}mP_{m,n-1}(t) - AnP_{m,n}(t) + A(n-1)P_{m,n-1}(t) \tag{2}$$

where it relates the probability of having $m$ quarks and $n$ gluons at each branching step ($P_{m,n}$) for each branching step. $A\Delta t$ and $\tilde{A}\Delta t$ are the probabilities of quark bremsstrahlung and gluon fission within the infinitesimal interval $\Delta t$.

The GMD which assumes the quark bresstrahlung and gluon fission dominate, is then given by:

$$P_{GMD}(\bar{n}, k', k) = \frac{\Gamma(n+k)}{\Gamma(n-k'+1)\Gamma(k'+k)} (\frac{\bar{n}-k}{\bar{n}+k})^{n-k'} (\frac{k'+k}{\bar{n}+k})^{k'+k} \tag{3}$$

Where the $\Gamma$ function is the typical $\Gamma$ function. Note that the GMD will be reduced to the NBD if we set $k' = 0$. While the NBD has given good fits for the energy levels of 200, 540 and 900 GeV multiplicity spectrum, the NBD fails to describe the 900 GeV non-single-diffractive data for large pseudorapidity intervals in the peak region of the distribution. Previous analysis has shown that the GMD and NBD fitting is nearly indistinguishable at the previously stated energies and also manages to describe $e^+e^-$ , $pp$ and $p\bar{p}$ collisions.

### 3.1 Forward-Backward Multiplicity Distribution

Taking cluster size and the GMD into account for the Chou-Yang model, we come up with the equation:

$$\begin{aligned} P(n,z) &= P_{GMD}(n) \times C^{n/k}_{(n_F)/2k} \\ &= P_{GMD}(n) \times C^{n/k}_{(n+z)/2k} \end{aligned} \tag{4}$$

The parameters $k$ and $k'$ are found by minimizing the $\chi^2$ for a range of 1 to 10 for $k'$ and 0.01 to 10 for $k$, the difference is due to the gamma factor in the GMD. For the multiplicity $n = 0$, we require $k'$ to be $\geq 1$ or we would get a negative $\Gamma$ function which is not applicable.

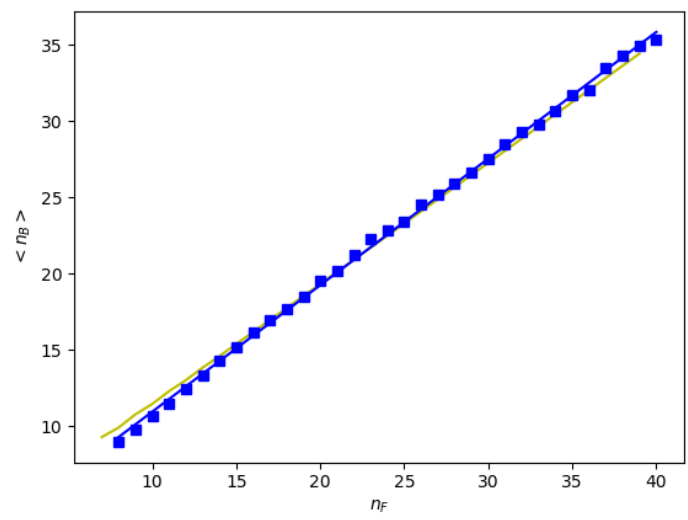


**Figure 1:** Forward-backward multiplicity of 7 TeV data. The squares represent the experimental data, the blue line represents the Linear Least Square fitting best fit line and the yellow line represents the foward-backward multiplicity as per the Chou-Yang model, using the GMD with $k = 0.01$ & $k' = 1.85$ with a cluster size of 2.58

As can be seen from the Figure, the Chou-Yang Model where the GMD is used for the non-stochastic multiplicity distribution describes the forward-backward multiplicity distribution fairly well. Here, the linear-least squares fitting parameters are 0.83 for the gradient and 2.67 for the y-intercept.

## 4 Conclusion

The forward-backward multiplicity distribution is aptly described by the Chou-Yang model. We've kept the stochastic component of the Chou-Yang model as the binomial distribution, however we've adapted it using the energy-dependent cluster size. As for the non-stochastic component of the Chou-Yang model, we've used the Generalized Multiplicity Distribution in place of the original KNO-scaling. As can be seen from Figure 1, the fitting of the adapted Chou-Yang model is comparable with the Linear Least Squares fitting of the forward-backward multiplicity spectra.

## 5 Future Outlook

The multicplicity data used in this analysis has not been corrected and therefore the parameters are still up for alteration. Parameters such as the cluster size and the values of $k$ and $k'$ used in the binomial distribution and the GMD respectively will have to be recalculated upon correction. As the LHC begins to ramp up to it's full capacity of 14 TeV, new data will be produced and it would be imperative in verifying phenomenological models like the Chou-Yang model. Hopefully through such phenomenological models, we would be able to provide a basis for future theoretical work to proceed onwards.

## References

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