Identifying jet-like events using multiplicity detectors in forward rapidities

Ranbir Singh
National Institute of Science Education and Research, HBNI, Jatni, INDIA

Outline:

- Motivation
- Analysis technique
- Results
- Summary

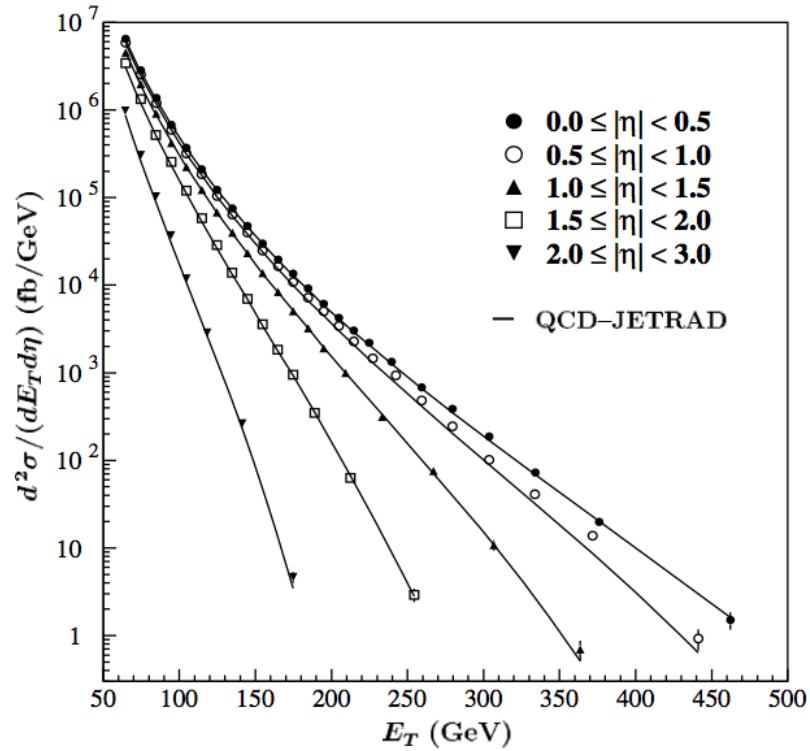
Motivation

- At LHC with large √s, multi-jet events may be produced with measurable cross-section – typical 3-jet events arising from qg -> qgg:gg -> ggg should appear in the ratio 0.3:1

  [1]Phys. Lett. B 212, 95 (1998).

  The partonic interaction of low "x" gluon and the high "x" quark will lead to a jet in forward direction.

- First measurement of inclusive jet production cross section in forward rapidities performed by D0 collaboration[2]



[2]D0 Collab., Phys. Rev. Lett. 86, 1707, 2001.

Jets in general produce localised particles density distribution which Are different compared to normal event in pp collisions

The aim of this study is to explore if this distiction of localised high particle density can be exploited to predict the jet direction or jet-like event

A multi-resolution wavelet analysis technique

The wavelet transformations have advantage over traditional Fourier methods in analyzing physical situations where the signal contains discontinuties and sharp spikes.

This analysis is performed to the data of PYTHIA monte carlo simulation for pp collisions at $\sqrt{s}$ = 7 TeV.

Haar wavelet: For an input represented by a list of 2^n numbers, the Haar wavelet transformation is to simply pair up input values, storing the difference and passing the sum, finally results in 2^n-1 differences and one final sum

For mathematical illustration, consider a one dimensional phase-space described by the dimensionless variable x in the interval [0,1]. Divide phase space in 2^j bins of size $\Delta x = 1/2^j$, where j is a positive integer $j < j_{max}$ corresponds to finest resolution that can be obtained

Let us consider a function f(x) represent any observable in this interval such that

$$f^{(j)}(x) = \sum_{k=0}^{2^j-1} f_k^j \, \phi_k^j(x) \qquad (1)$$

where $\phi_k^j(x)$ is given by

$$\phi_k^j(x) = \begin{cases} 1 & k/2^j \leq x < (k+1)/2^j \\ 0 & \text{otherwise} \end{cases} . \qquad (2)$$

f^j_k is the value of f(x) in the kth bin. The sample function f(x) can be written in various scales. For example, to find the structure at lower scale one can replace two adjacent bins 2k and 2k+1 by a single bin of size $2\Delta x = 1/2^{j-1}$

In new bin, defining f_k^{j-1} of the fuction as the average of the values in previous bins

$$f_k^{j-1} = \frac{1}{2}(f_{2k}^j + f_{2k+1}^j)$$

where, f_k^{j-1} are called mother function coefficients (MFCs)

Another information can be encoded is the difference $\tilde{f}^{(j-1)}(x) \equiv f^{(j)}(x) - f^{(j-1)}(x)$

Similarly can be represented as $\tilde{f}^{(j-1)}(x) = \sum_{k=0}^{2^{j-1}-1} \tilde{f}_k^{j-1} \, \psi_k^{j-1}(x)$

where, $\tilde{f}_k^{j-1}$ are called father function coefficients (FFCs). At a given scale j, FFCs measure the variation of the sampled distribution f between two adjacent bins

Analysis tools and data set details

Event generator: PYTHIA6

Processes: Minimum bias and jets

System: pp

Centre of mass energy: 7 TeV

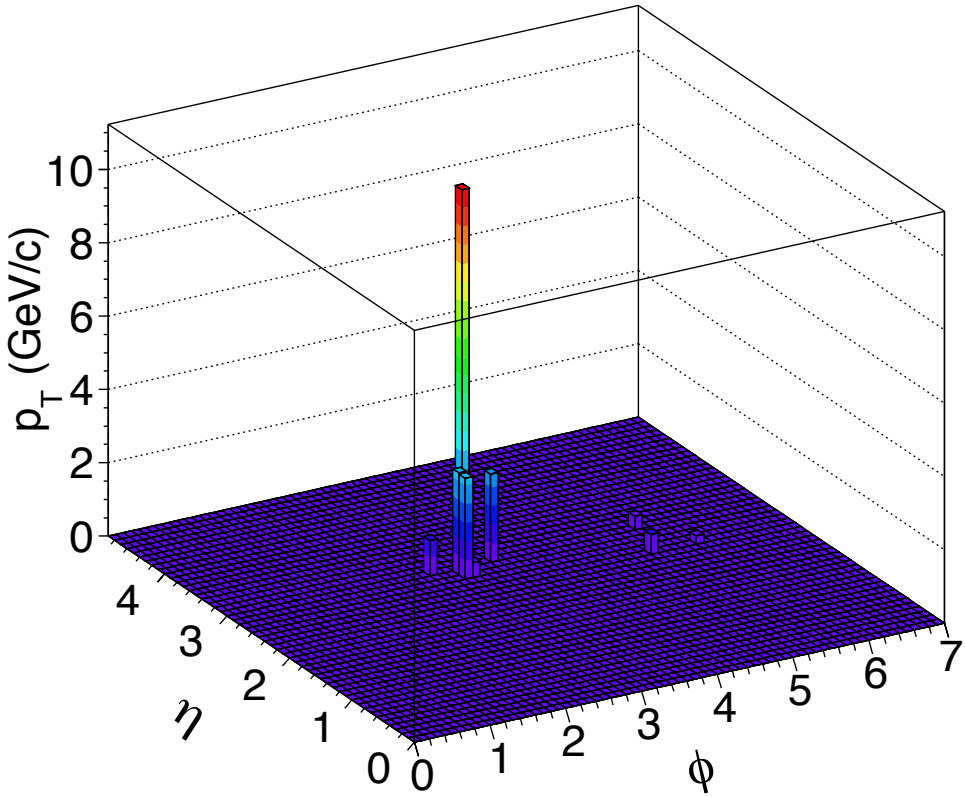
No. of events: 50k in each case

This study is aimed on the present high energy experiments STAR at RHIC and ALICE at LHC. In the forward region of such experiments there are a set of charged particle detectors and a photon multiplicity detector.

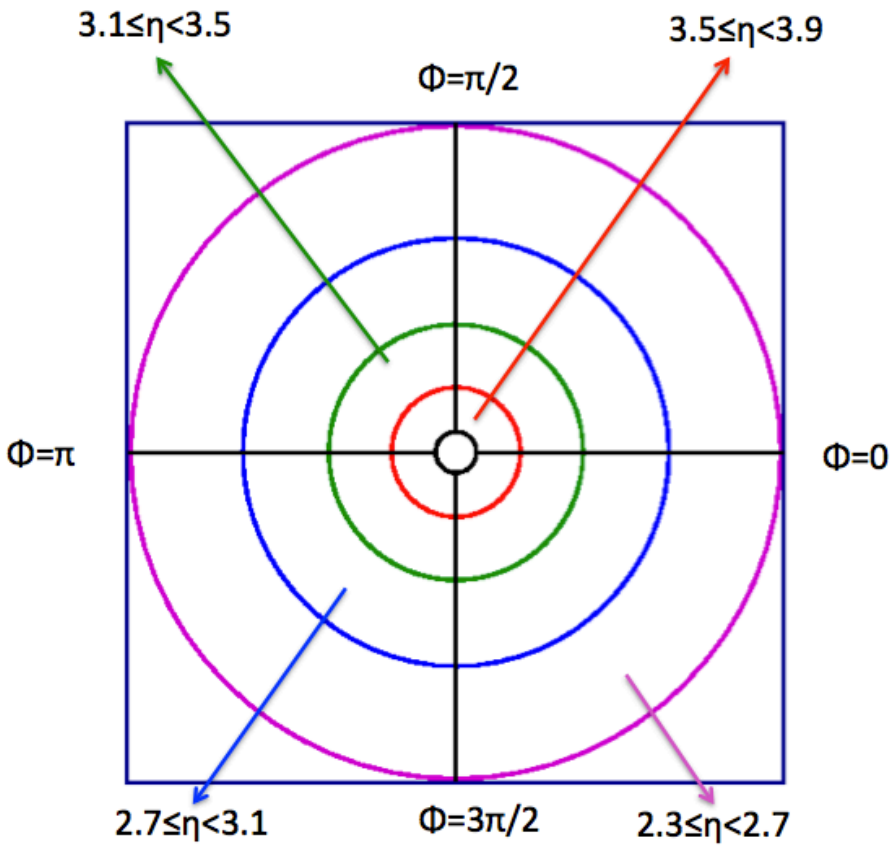
Note: Throughout this presentation results from generator level are called as MC truth and the results after the application of detector response are called as Digits.

Charged particle distribution in a jet event

A typical PYTHIA simulated jet event in pp, $\sqrt{s}$ = 7 TeV
- Jet E_T > 20 GeV
- Rapidity range: 2.3 < η < 3.9



Schematic of binning scheme in η-ϕ



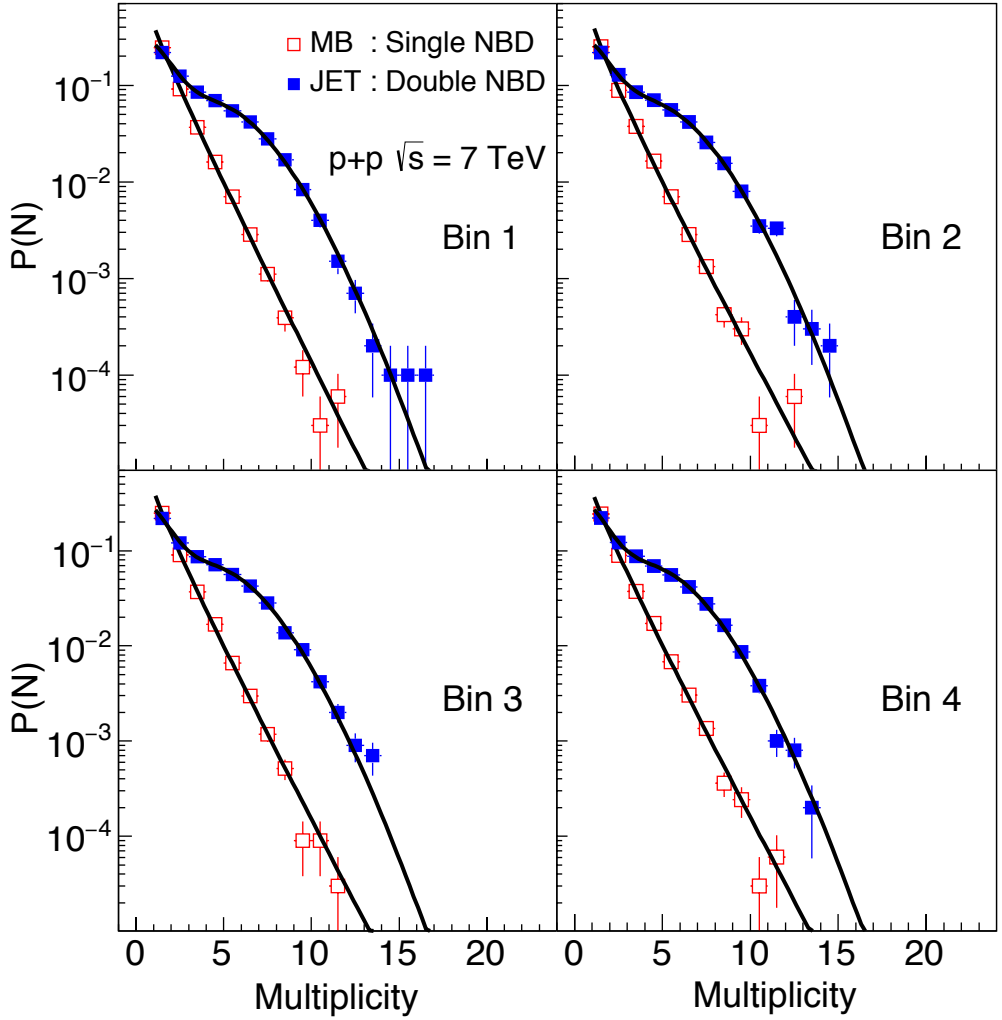
Bin	Bin name (η, ϕ)	η - range	ϕ - range
1	(1,1)	$2.3 \leq \eta < 2.7$	$0 \leq \phi < \pi/2$
2	(1,2)	$2.3 \leq \eta < 2.7$	$\pi/2 \leq \phi < \pi$
3	(1,3)	$2.3 \leq \eta < 2.7$	$\pi \leq \phi < 3\pi/2$
4	(1,4)	$2.3 \leq \eta < 2.7$	$3\pi/2 \leq \phi < 2\pi$
5	(2,1)	$2.7 \leq \eta < 3.1$	$0 \leq \phi < \pi/2$
6	(2,2)	$2.7 \leq \eta < 3.1$	$\pi/2 \leq \phi < \pi$
7	(2,3)	$2.7 \leq \eta < 3.1$	$\pi \leq \phi < 3\pi/2$
8	(2,4)	$2.7 \leq \eta < 3.1$	$3\pi/2 \leq \phi < 2\pi$
9	(3,1)	$3.1 \leq \eta < 3.5$	$0 \leq \phi < \pi/2$
10	(3,2)	$3.1 \leq \eta < 3.5$	$\pi/2 \leq \phi < \pi$
11	(3,3)	$3.1 \leq \eta < 3.5$	$\pi \leq \phi < 3\pi/2$
12	(3,4)	$3.1 \leq \eta < 3.5$	$3\pi/2 \leq \phi < 2\pi$
13	(4,1)	$3.5 \leq \eta < 3.9$	$0 \leq \phi < \pi/2$
14	(4,2)	$3.5 \leq \eta < 3.9$	$\pi/2 \leq \phi < \pi$
15	(4,3)	$3.5 \leq \eta < 3.9$	$\pi \leq \phi < 3\pi/2$
16	(4,4)	$3.5 \leq \eta < 3.9$	$3\pi/2 \leq \phi < 2\pi$

- η-ϕ coverage is divided in 16 bins
- Multiplicity in each bin is the input for wavelet analysis

Charged particle multiplicity distribution in minimum bias (MB) and jet events

Multiplicity distribution of charged particles in four particular η-ϕ bins where we allow the jet to fall on

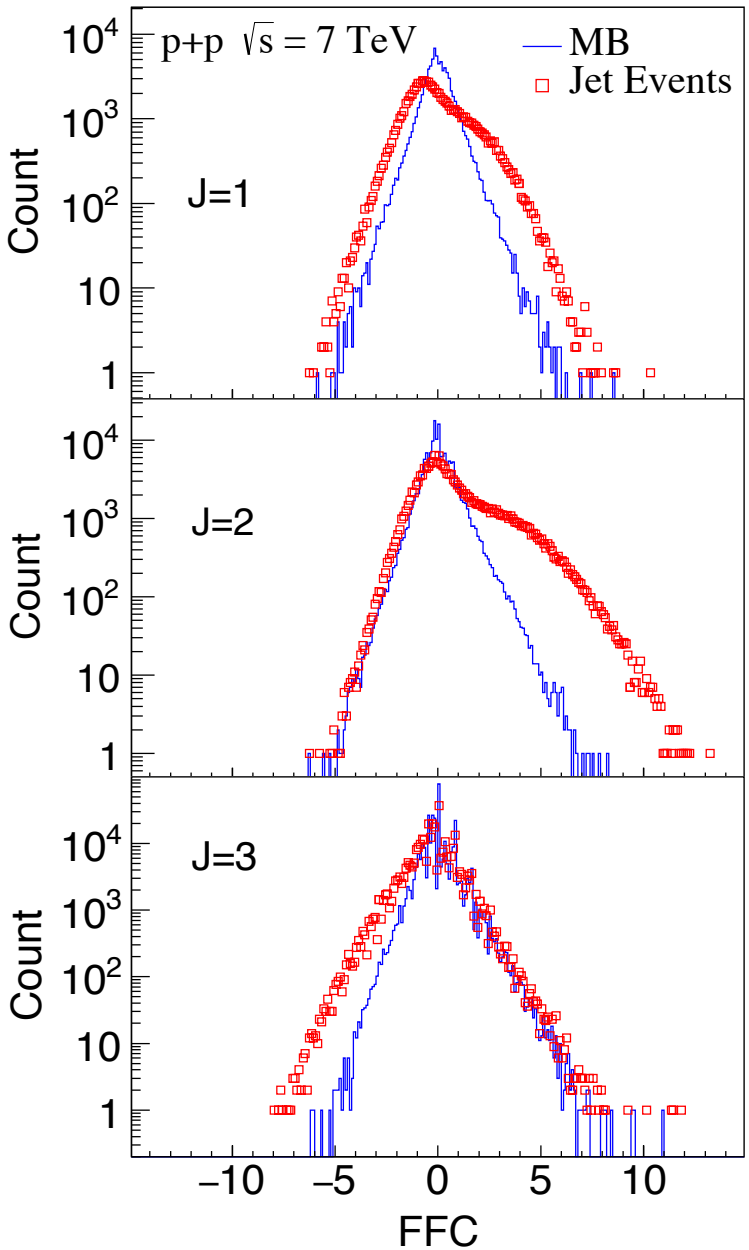
- ❑ MB distributions are fitted with single NBD
- ❑ Jet event distributions are fitted with double NBD
  - The double NBD is required to account for soft and hard processes



FFCs distributions from MC truth

FFCs distributions for MB and jet events from MC truth

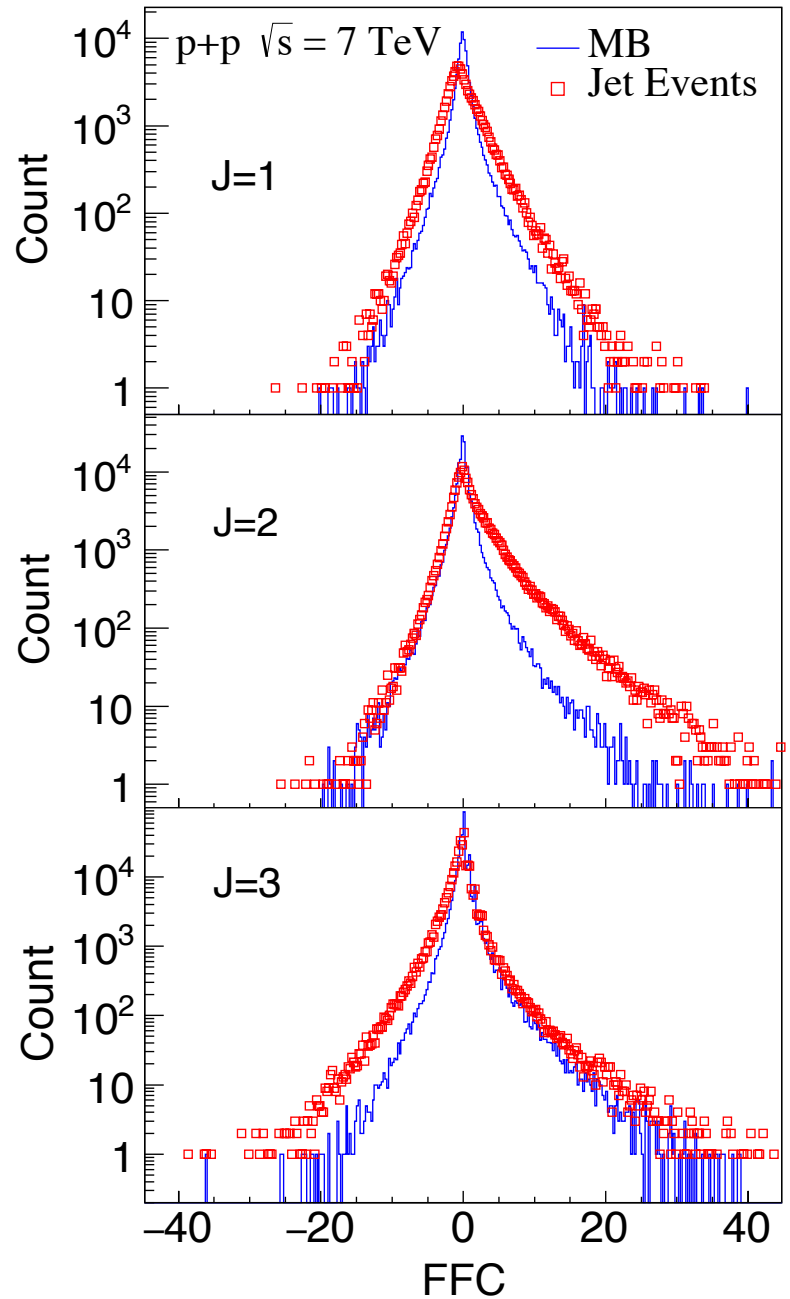
- The distribution is broader for jet event - broader FFCs distributions reflect more bin-to-bin fluctuations
- Large difference is seen for scale J=2 - the scale describe the size of the jet



FFCs distributions after applying detector response

FFCs distributions after the application of detector response show similar behavior as in case of MC truth

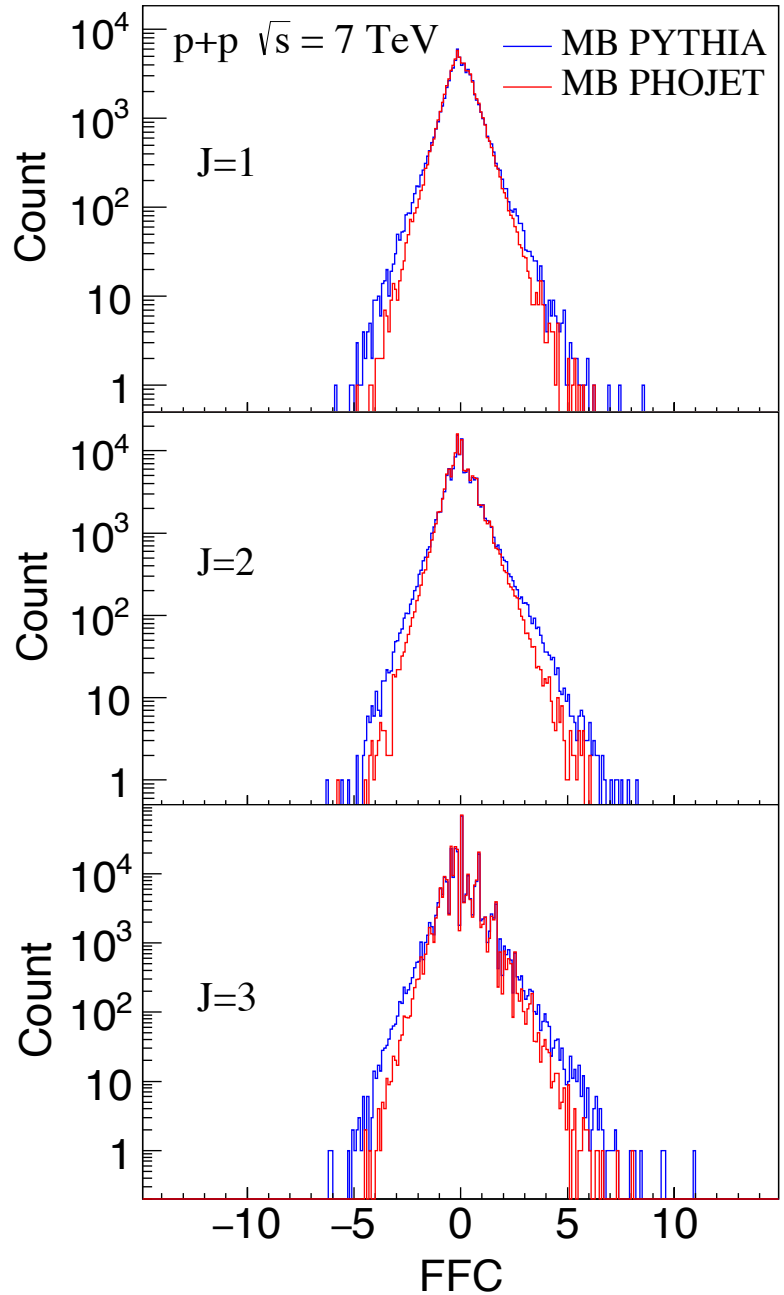
- The distribution is broader for jet event - broader FFCs distributions reflect more bin-to-bin fluctuations
- Large difference is seen for scale J=2 - the scale describe the size of the jet



Model dependence

To check the model dependence analysis is carried out using PYTHIA6 and PHOJET

- FFCs distributions are in good agreement for different scales
  - no model dependence is observed

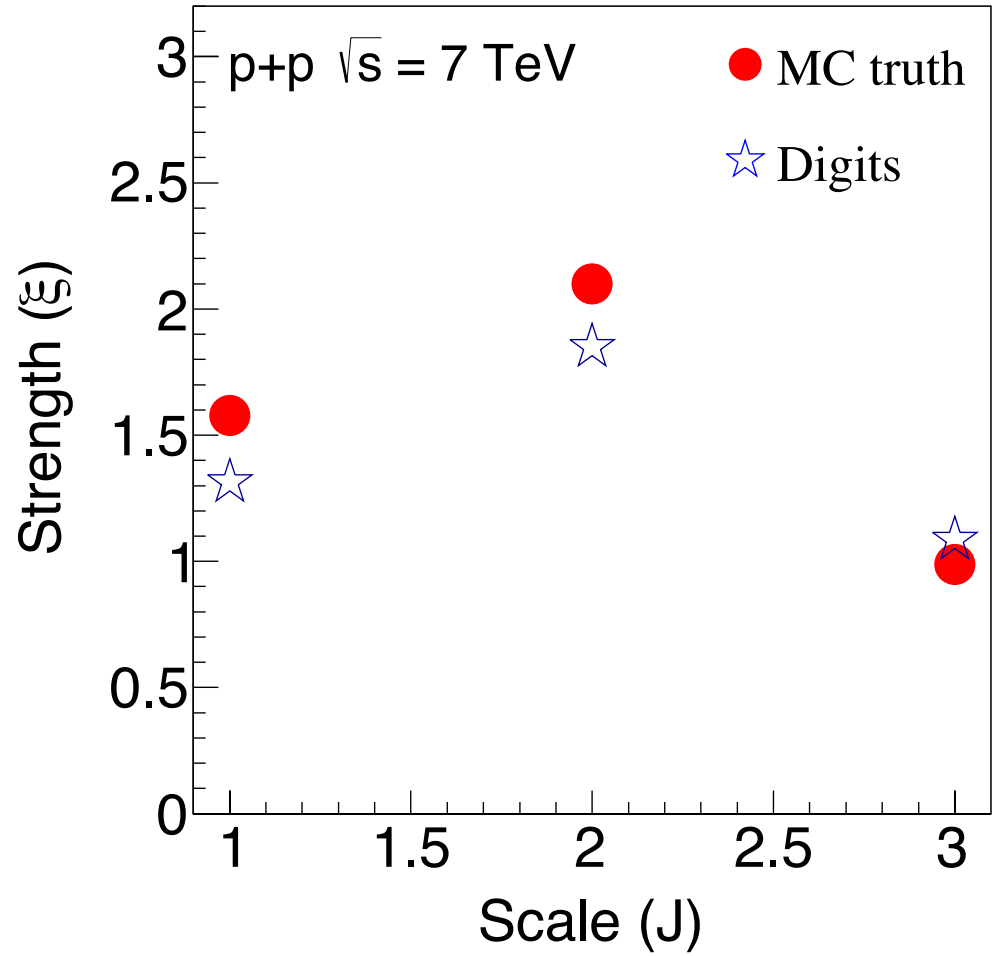


Strength parameter ξ vs scale (J)

To quantify the results we introduce a strength parameter ξ

$$\xi = \frac{\sqrt{\sigma_{jet}^2 - \sigma_{mb}^2}}{\sigma_{mb}}$$

where, σ_{jet} and σ_{mb} are widths of the FFCs distribution for jets and MB events

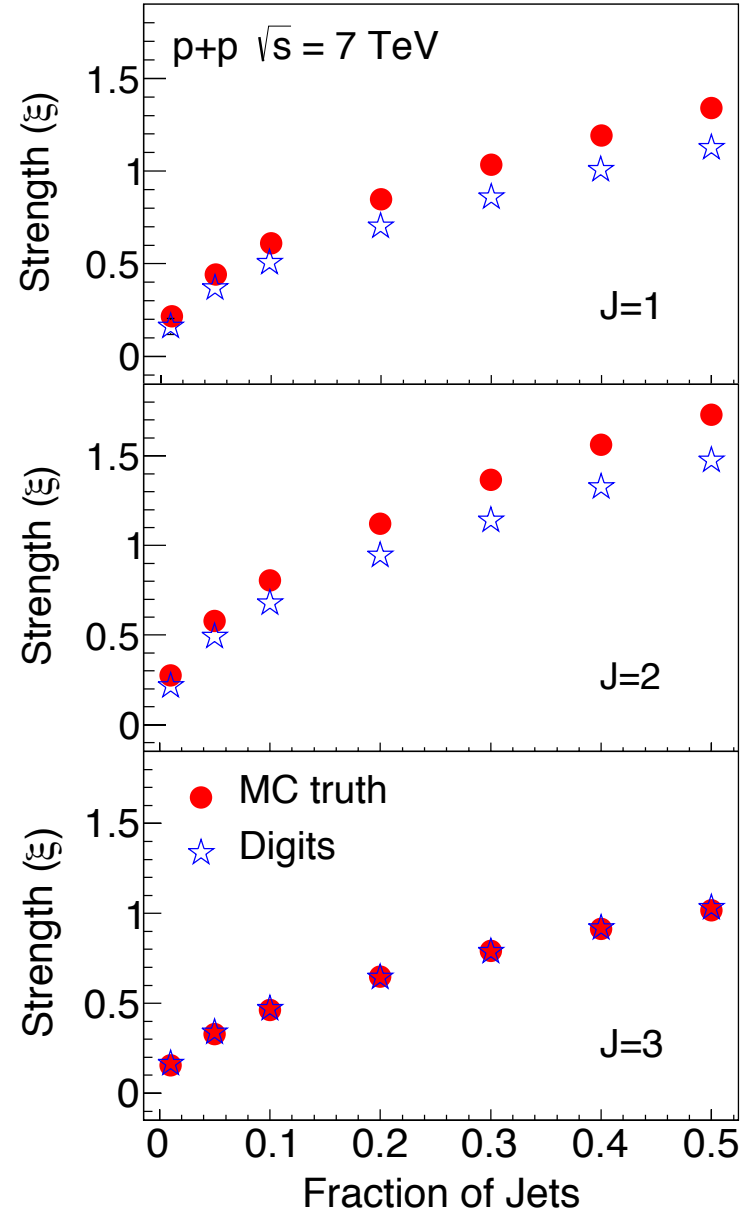


- The strength parameter ξ, determines the deviation from normal distribution
  - the maximum value of ξ is for J=2

Strength parameter ξ with varying jet fraction

Strength parameter ξ is measured for sevenn event samples with jet event fraction 0.01, 0.05, 0.1, 0.2, 0.3, 0.4 and 0.5

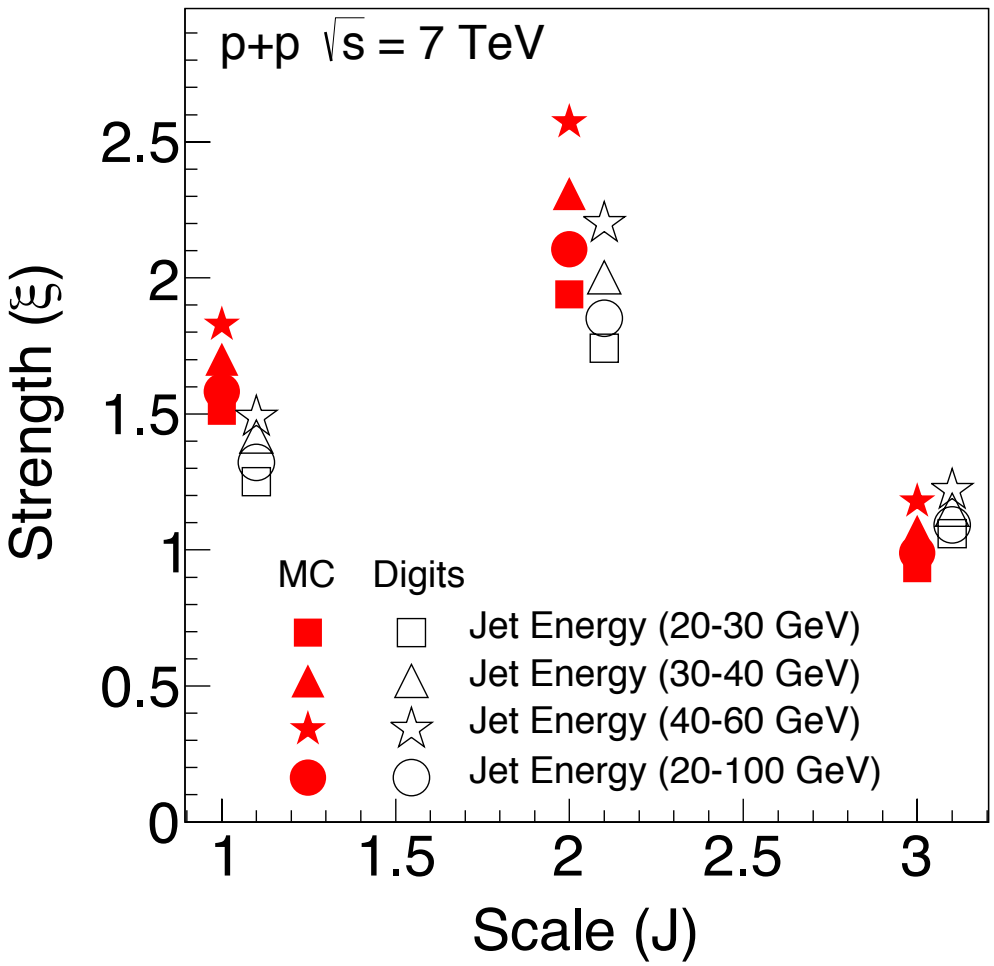
- ξ increases with increasing jet event fraction
- Magnitude is higher for scale J=2



Energy dependence

Strength parameter dependence on jet transverse energy is studied for four samples with jet ET ranging: 20-30 GeV, 30-40 GeV, 40-60 GeV and 20-100 GeV

- ❑ ξ value is highest for jet E_T = 40-60 GeV i.e. for highest jet E_T case
- ❑ Magnitude is higher for scale J=2 in all cases

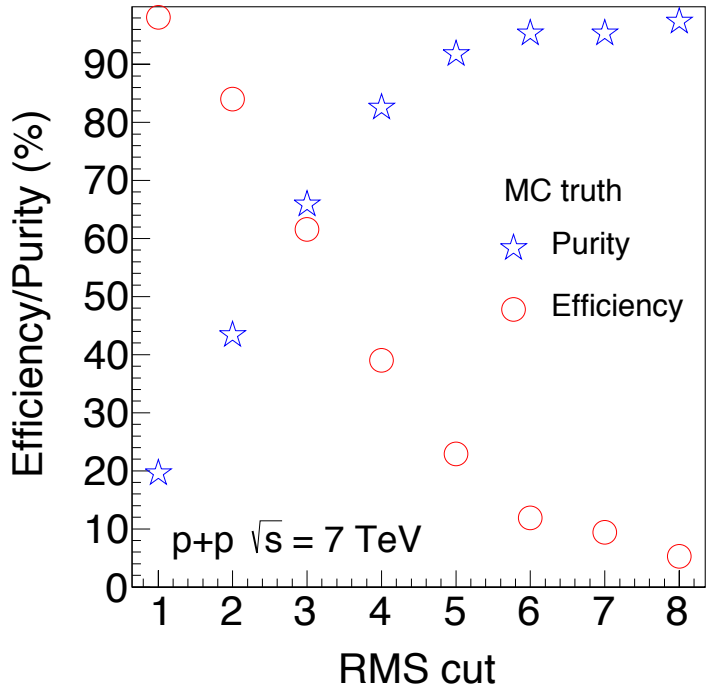


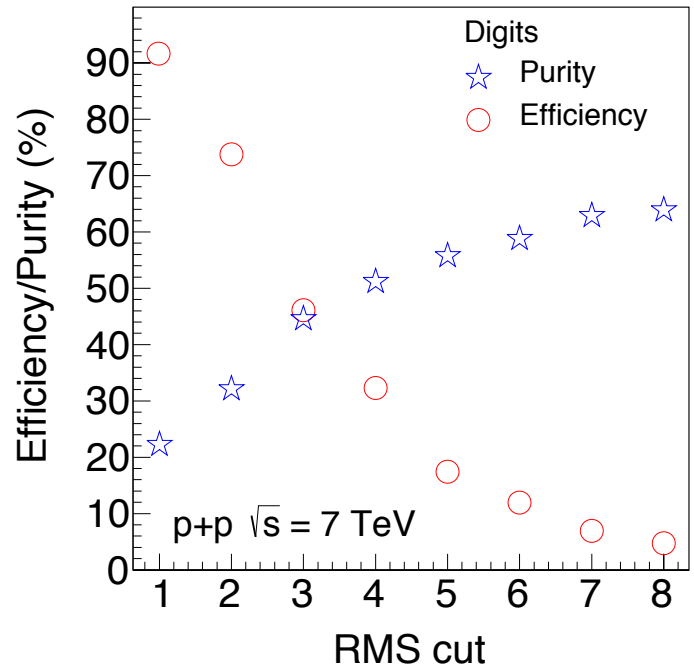
Efficiency and purity in selecting jet-like events

Efficiency and purity is calculated by using different rms cuts from normal distribution on a sample of MB+jet evnets

$$Efficiency = \frac{N_j}{N_{ja}} \qquad Purity = \frac{N_j}{N_{jlike}}$$

where, N_j = No. Of jet events identified, N_{ja} = No. Of jet events added in MB sample and N_{jlike} = No. of jet-like events





A cut of 3 rms of MB FFCs distributions gives efficiency and purity values of the order of 46%

Summary

- ✓ We have presented a multi-resolution wavelet analysis technique to identify jet-like events using a multiplicity detector in forward rapidities
- ✓ The simulation study shows the good sensitivity towards selecting jet-like events
- ✓ The values of ξ is 0.22, 0.65 and 1.42 for event samples with 1%, 10% and 50% jet events, respectively
- ✓ With a 3 rms cut of MB FFCs distribution, jet events can be identified with efficiency and purity of about 46%

Acknowledgement

We would like to thank Dr. Y. P. Viyogi for initiating fruitful discussions on tagging jet-like events using a multiplicity detector.