Studies of QCD jets in CMS

Outline

- Introduction : QCD dijets
- Event generation and selection
- Dijet Cross section and event rate
- Analysis of Generated and Reconstructed jets
- Summary and Outlook

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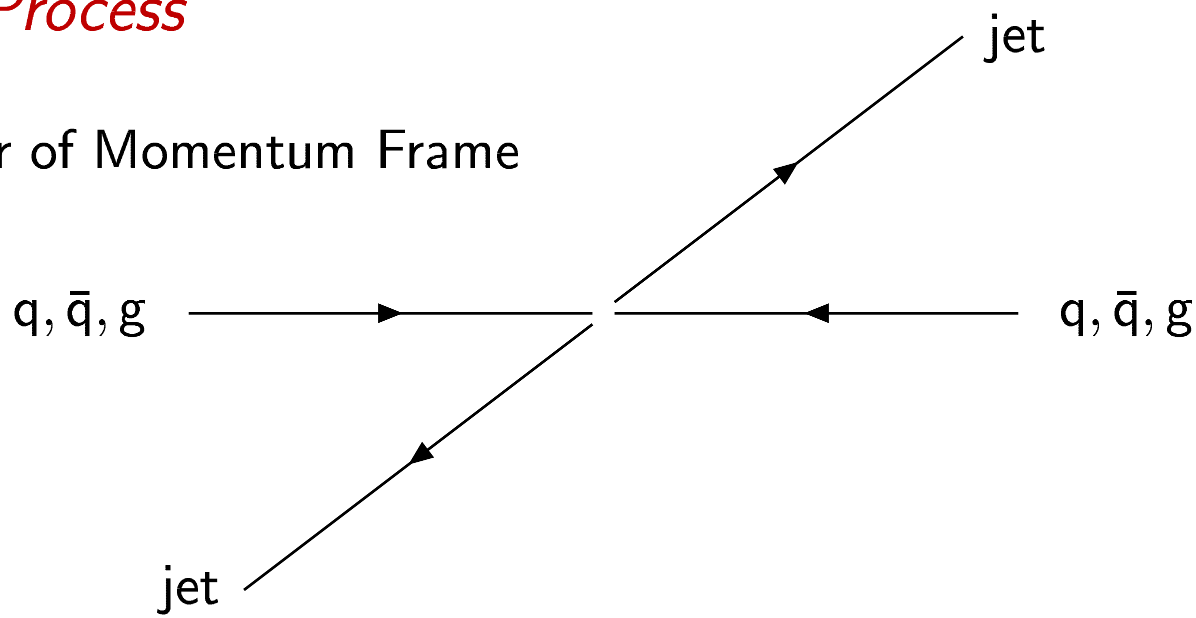
30 June , 2006

IndiaCMS meet, TIFR

$2 \to 2$ *Process*



Only hard QCD processes are considered

$$
\begin{array}{lclclcl}
f_i f_j & \to & f_i f_j & \quad & f_i g & \to & f_i g \\
f_i \bar{f}_i & \to & f_k \bar{f}_k & \quad & gg & \to & f_k \bar{f}_k \\
f_i \bar{f}_i & \to & gg & \quad & gg & \to & gg
\end{array}
$$

QCD dijets

Motivation: Why study dijets?

- Simplicity
  - Inclusive dijet production ($pp \rightarrow 2jets + X$) is the dominant hard process in LHC
  - No significant background
- Calorimeter
  - Dijet p_T balance will be used to calibrate HCal in-situ
  - Dijets test that calorimeters and their triggers are functioning
- Timeliness
  - Measurements using only Calorimetry can be done quickly
- Physics
  - Test of QCD and parton distributions at high Q^2

q The first step is *triggering* on jets.

q Measuring dijet distribution enables us to measure the QCD distribution.

Event Generation and Reconstruction

q Events generated using PYTHIA

q p_T bins specified in pre-challenge sample for studying mass distribution (discussed later)

q structure function chosen; PDF: CTEQ 5L (LO, $\alpha_s(M_z) = 0.127$)

q Reconstruction of jets

q Iterative cone jet algorithm used

q Cone radius R = 0.5

q Jet E_T seed cut = 7.0 GeV

q Event selection (pp $\rightarrow$ 2jets + anything)

q Find the two jets in the event with highest p_T: leading jets

q Require each leading jet to have $|\eta| \leq 1$

Trigger table: Pre-scaling factors

We concentrated only on HLT which are tighter cuts on the distribution.
Trigger values applied to see the significance of low and high regimes of p_T.

Jet Trigger	L1 Jet Trigger			HLT Jet Trigger			Total Prescale
	$p_T(E_T)$ (GeV)	Prescale (1/N)	Rate (KHz)	$p_T(E_T)$ (GeV)	Prescale (1/N)	Rate (Hz)	
High	177	1	~ 1	657	1	~ 1	1
Med	177	1	~ 1	350	30	~ 1	30
Low	177	1	~ 1	180	600	~ 1	600
Tiny	90	20	~ 1	90	600	~ 1	12000

- In practice one multiplies the dijet mass distribution with the pre-scaling factors to get the dijet event rate distribution for a given luminosity.

- The *tiny* trigger provides sample of low E_T jets to study calibration and fake rates.

Data Sample and Software

- The same p_T intervals were used as in DC04 pre-challenge data samples made by Haifeng Pi:

  - 0, 15, 20, 30, 50, 80, 120, 170, 230, 300, 380, 470, 600, 800, 1000, 1400, 1800, 2200, 2600, 3000, 3500, 4000
- All samples produced with no pile-up at an integrated luminosity of $1fb^{-1}$
- Softwares used:
  - Generator: CMKIN_4_3_1 with Pythia
  - Simulation and reconstruction: FAMOS_1_4_0

Dijet Mass Analysis

- Dijet mass:

$$\mathrm{M}_{jj} = \sqrt{(E_1 + E_2)^2 - (p_x^1 + p_x^2)^2 - (p_y^1 + p_y^2)^2 - (p_z^1 + p_z^2)^2}$$

- Cross section (σ) for individual bins (in pb)
- differential cross-section ($\frac{d\sigma}{dM_{jj}}$) plotted against the dijet mass in GeV.
- We bin the dijet mass in such a way that bin size increases with mass
- While adding different bins proper normalisation needs to be done taking the σ into account.
- We note

$$N = \mathcal{L}\sigma$$

hence

$$\mathcal{L} = \frac{N}{\sigma}$$

hence given a luminosity one calculates the event rate per fb^{-1}.

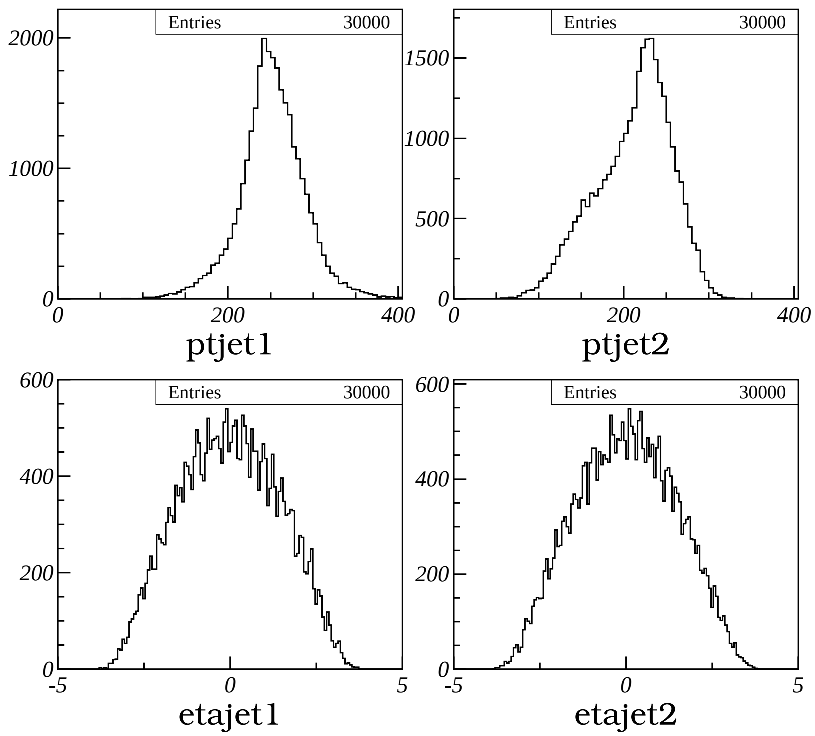
Cross section table

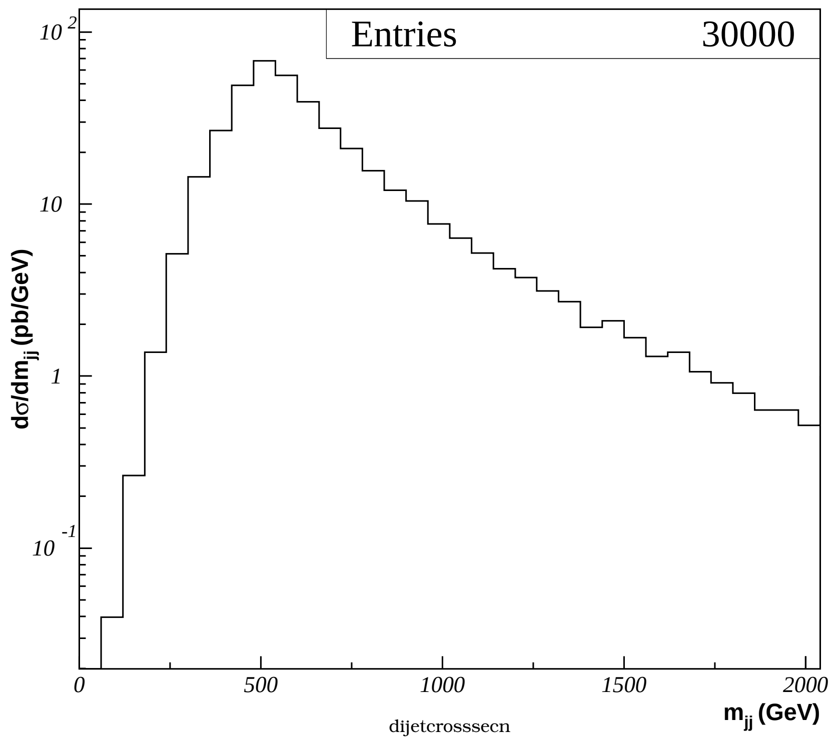
p_t Range (GeV)	cross-section (mb)	p_t Range (GeV)	cross-section (mb)
$0 - 15$	5.522E + 01	$470 - 600$	6.845E − 07
$15 - 20$	1.450E + 01	$600 - 800$	2.032E − 07
$20 - 30$	6.264E − 01	$800 - 1000$	3.549E − 08
$30 - 50$	1.546E − 01	$1000 - 1400$	1.079E − 08
$50 - 80$	2.075E − 02	$1400 - 1800$	1.049E − 09
$80 - 120$	2.941E − 03	$1800 - 2200$	1.446E − 10
$120 - 170$	5.002E − 04	$2200 - 2600$	2.378E − 11
$170 - 230$	1.006E − 04	$2600 - 3000$	4.268E − 12
$230 - 300$	2.393E − 05	$3000 - 3500$	8.444E − 13
$300 - 380$	6.381E − 06	$3500 - 4000$	9.718E − 14
$380 - 470$	1.885E − 06		

cross-sections are obtained by running stand-alone pythia for those given ranges and for the above mentioned hard QCD processes. CTEQ 5L.

Typical distributions for one particular 'bin'

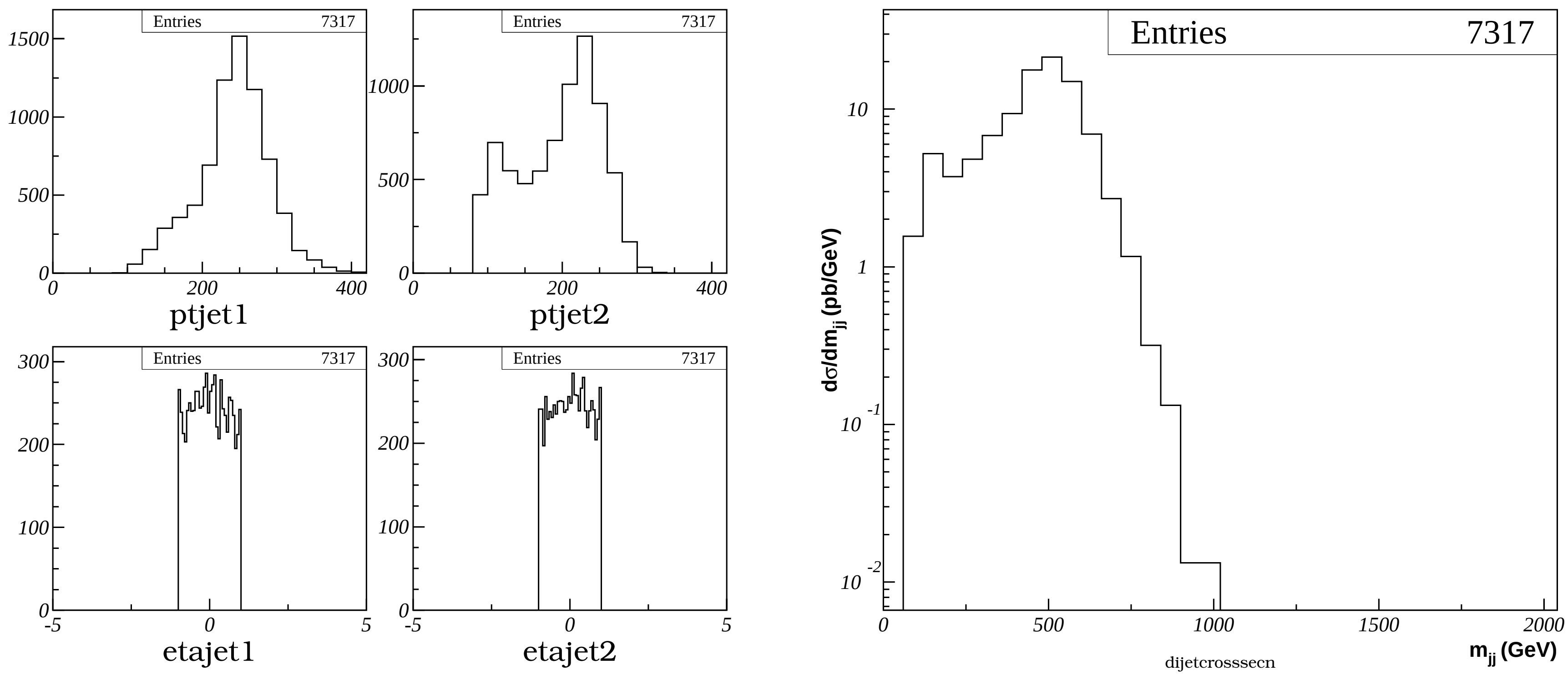
- Shown here is p_T and η distributions for the highest and next highest momentum jets for the range $230 - 300$ GeV. Also shown here is the dijet mass distribution for that particular bin.



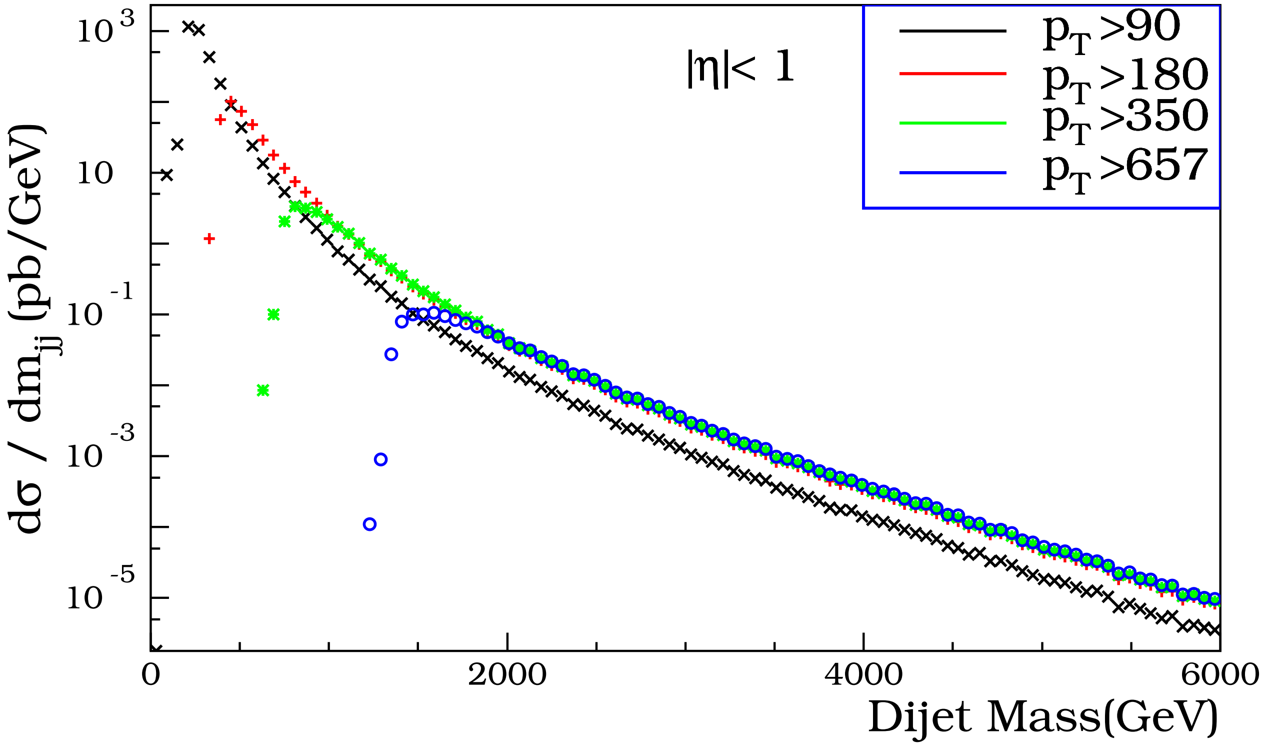


Typical distributions for one particular 'bin' after cuts

After we apply $|\eta| \leq 1$ and $p_T > 90$GeV

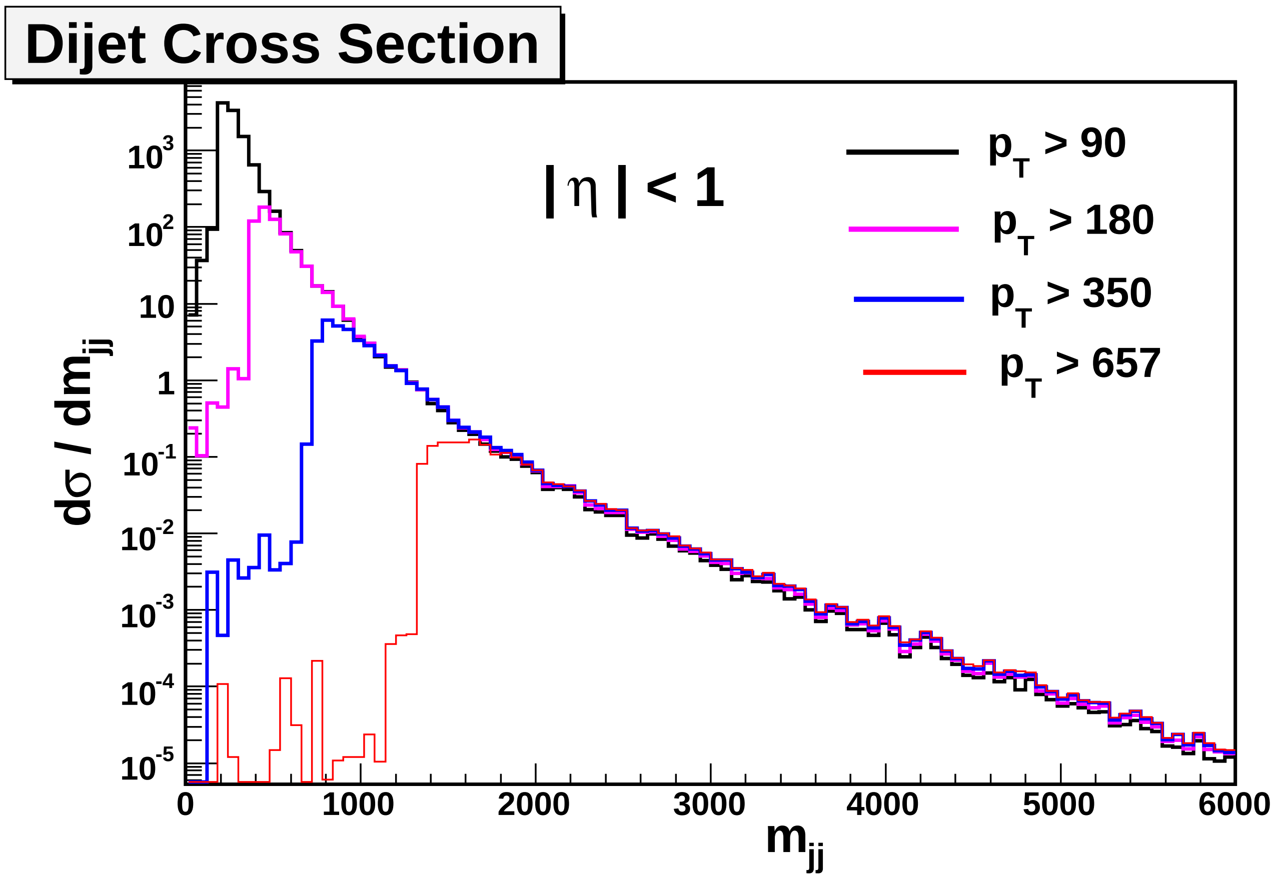


Dijet cross-section from triggers



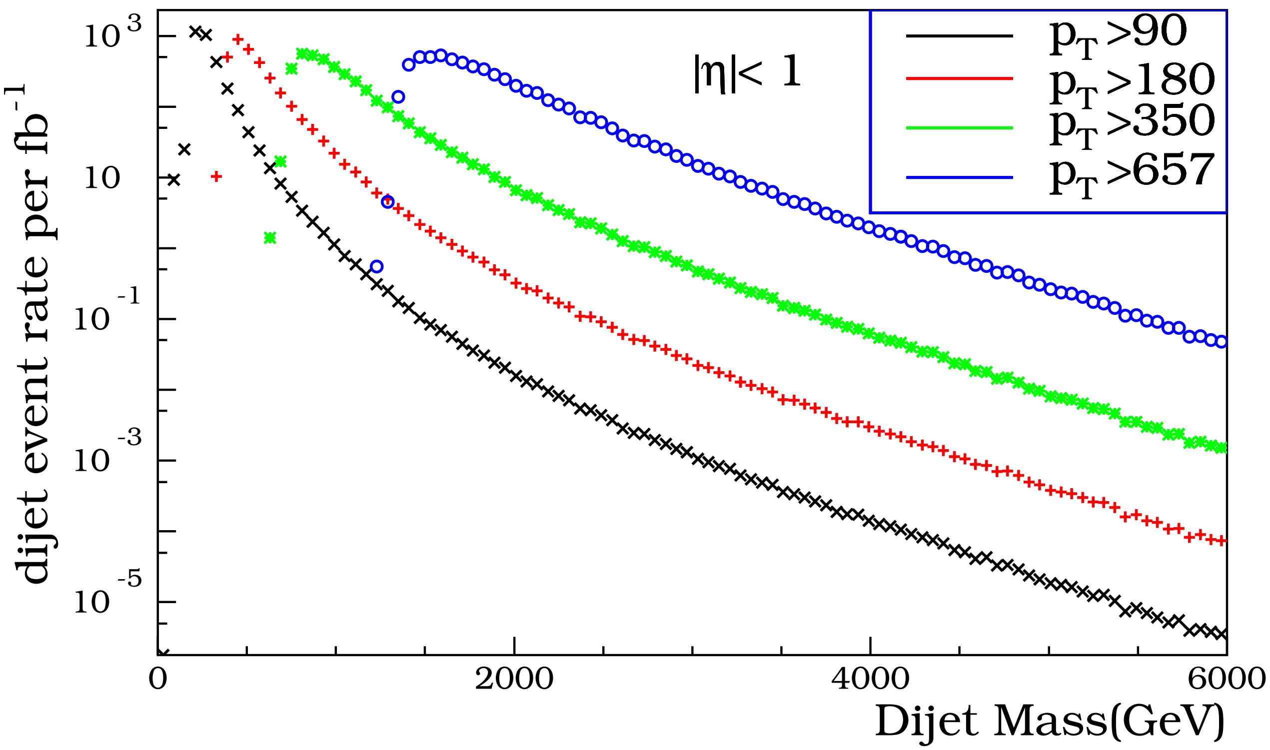
Done by generating events in CMKIN using Pyhtia.

Dijet cross-section - Famos



Dijet cross-section ($\frac{d\sigma}{dM_{jj}}$) distribution using reconstructed data in FAMOS (FAMOS_1_4_0).

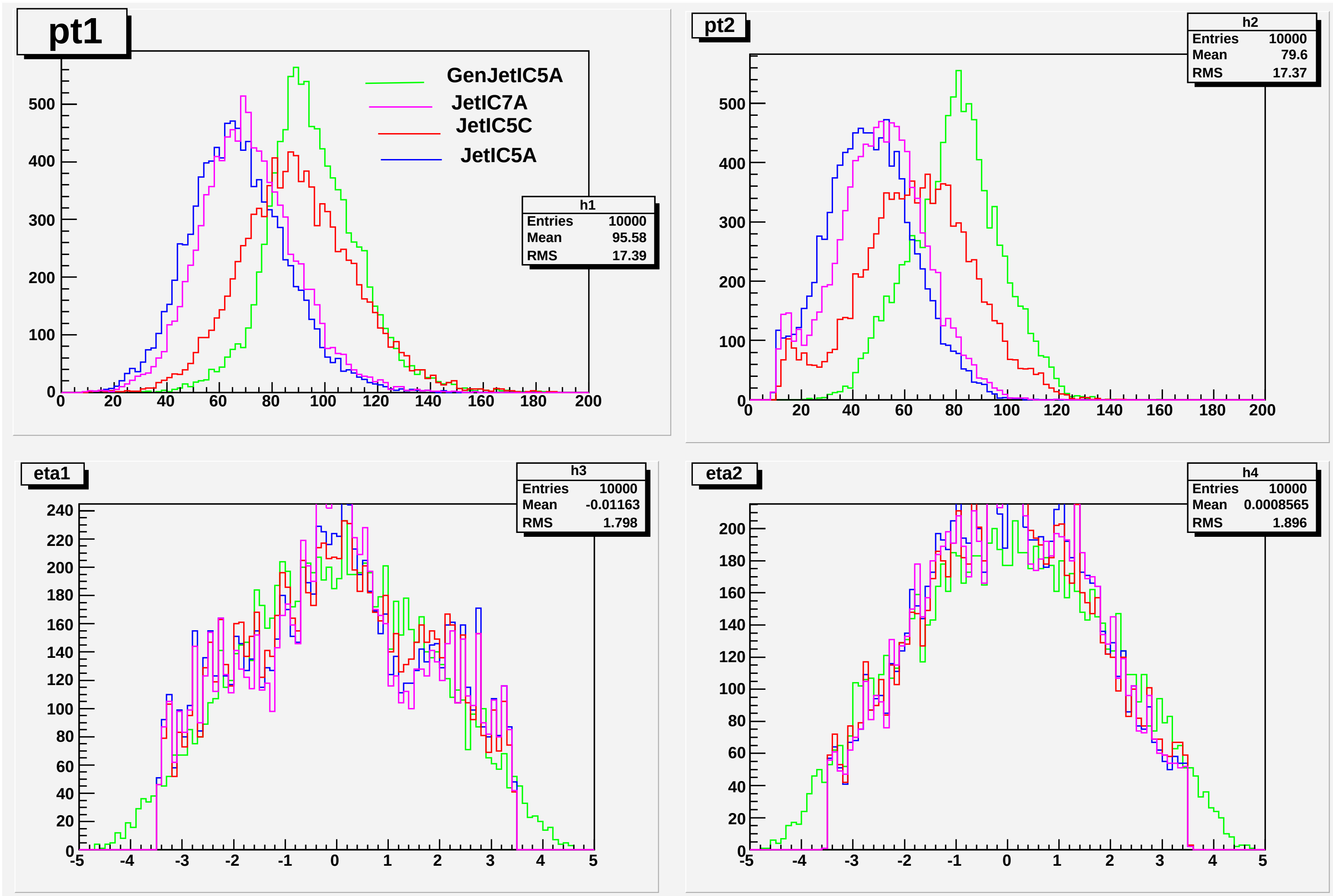
Dijet event rate from triggers



Trigger rate estimated here from single sample with varying p_T cut applied offline and considering the effect of HLT only.

Done by generating events in CMKIN using Pyhtia.

Generated and Reconstructed data in FAMOS



Hadronic Event shape and Jet productions

- Hadronic event shapes are tools to study both the amount of gluon radiation and the details of hadronization process.

- Events from $q\bar{q}$ final states without hard gluon radiation result in two collimated back-to-back jets of hadrons.

- Emission of one hard gluon leads to planar 3-jet events.

- Emission of two or more energetic gluons can cause non-planar multi-jet event structures.

- QCD predicts scaling violations for observables that do not depend on absolute energies or momenta, eg. *thrust*.

- Scaling violations caused by the energy dependence of α_s which determines the amount of gluon radiation.

- In LO the probability of gluon radiation is proportional to α_s.

Event Shape Variables

A typical event-shape observable is thrust, T, defined as a normalized sum of momentum components of all particles of a given event along a specific axis, the axis such that T is maximised.

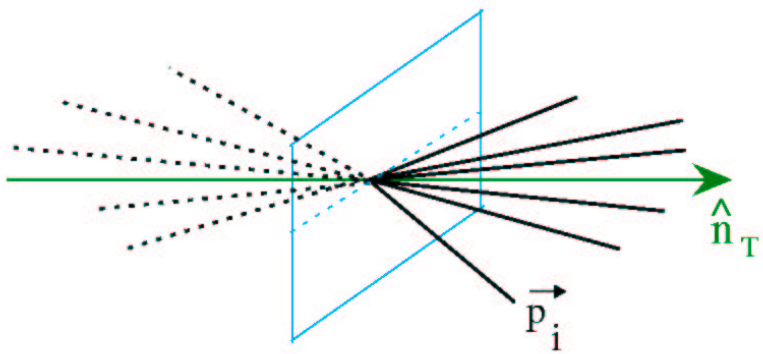
Thrust, Major, Minor, Oblateness, $\cdots$:

$$\mathsf{T} = \left(\frac{\sum_i |\mathrm{p_i} \cdot \hat{\mathrm{n}}|}{\sum_i |\mathrm{p_i}|} \right)_{\mathrm{max}}$$

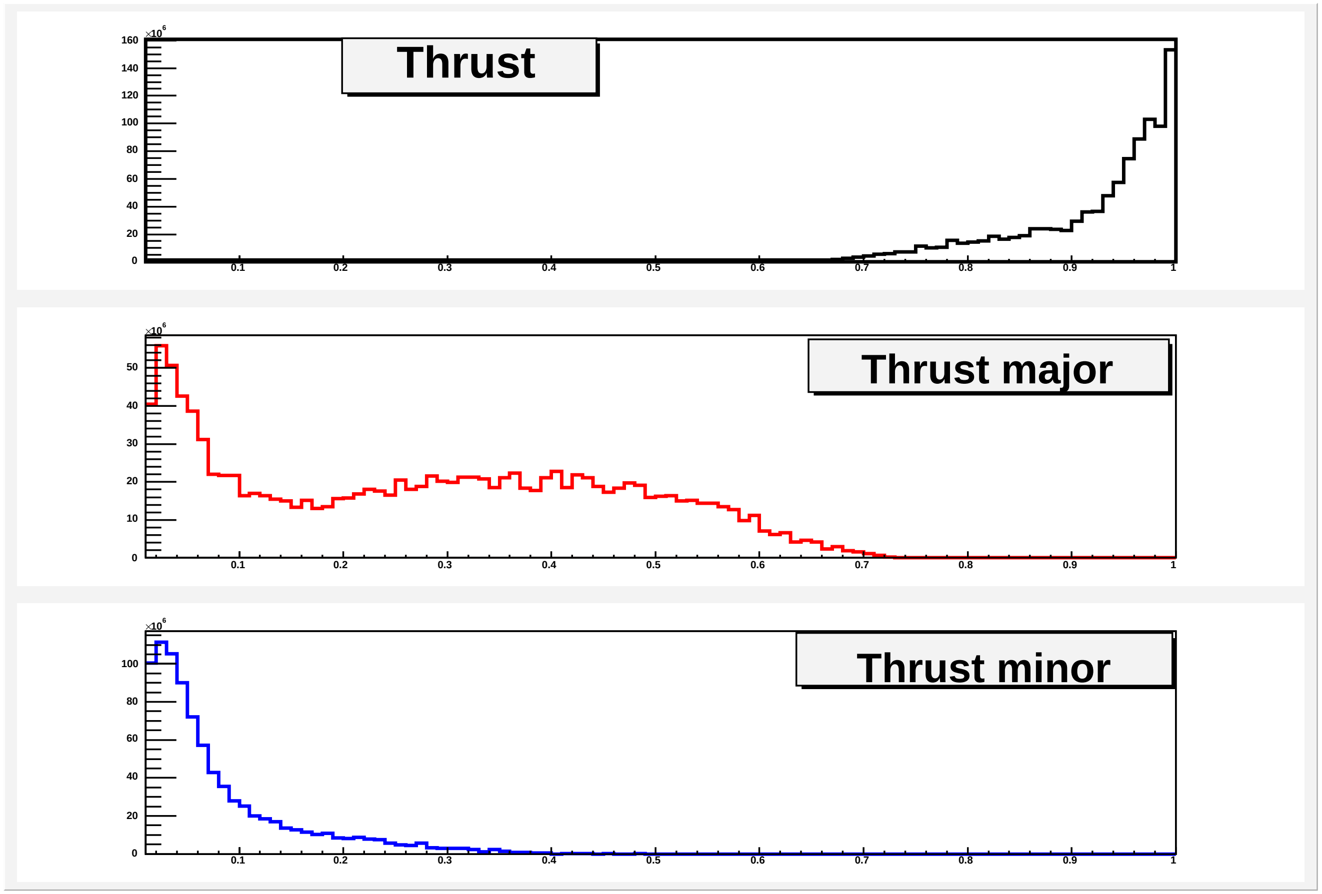
where the thrust axis $\hat{n}_T$ is defined as the unit 3-vector $\hat{n}$ which maximises the expression.

$\mathrm{T_{major}}$ defined like T but in plane perpendicular to $\mathrm{n_T}$

$\mathrm{T_{minor}}$ computed along minor axis orthogonal to $\mathrm{n_T}$ and major axis



Thrust distribution



Done using GenJetIC5A in FAMOS ExRootAnalysis

Summary and Outlook

- We plan to analyse these event shape variables in dijet event sample taking into account the effect of trigger biases.

- Our main aim was to set up the machinery which is almost done. Now we want to use the data available for the given luminosity.

- We have started using CMSSW framewrok (CMSSW_0_7_0).

- We have to include other event shape variables.

- These distributions will be compared with the expectations from *resummed calculations*. This will give the sensitivity to measure α_s at the LHC and also the structure of underlying events.

back up