Update on Multijet Study

Outline

- Event selection and Monte Carlo sample.
- Different topological properties of 3(4) parton cases.
- Effects of Energy and Position resolutions on multijet variables.

QCD Meeting, November 13, 2008

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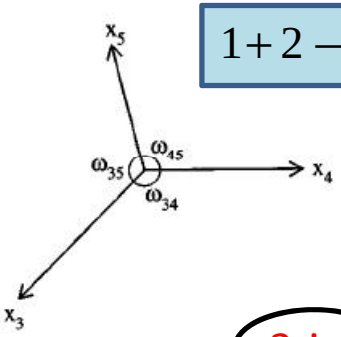
Event Selection and MC data used

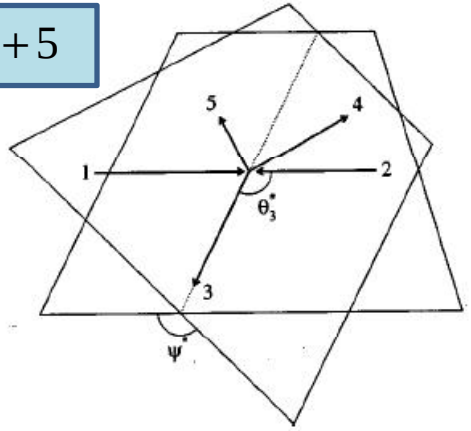
- CMSSW_2_0_7 is used for this analysis.
- One specific trigger jet sample is used for this anlysis:

  CSA08 _QCDJetEt50_S156 sample with luminosity 10 pb^{-1} . *This sample has an equivalent pthat-min of 75 GeV. with 4,010,400 events being produced*.
- GenJets and Corrected (L2L3 correction) Calojets are compared.
- Event selection was based on Corrected Calojets for CSA08 sample.
- Jets are selected in the $|\eta| < 3.0$ region (upto endcap).
- Two jet algorithms are used for this analysis: SiSCone (R=0.7) and Kt (D=0.6).
- For 3(4) jet studies the most energetic jets are considered, the jets being ordered in their transverse energy (Et).
- The jets are boosted to their centre of mass frame and ordered in descending order of their Energies (E) in the boosted frame.
- **Event selection** was done in the following way:
  1. **HLT conditions (threshold of 110 GeV on leading jet Pt) is applied.**
  2. **An additional threshold (50 GeV) applied on all corrected jets.**
  3. **Inclusive 3 jet and 4 jet events are selected.**

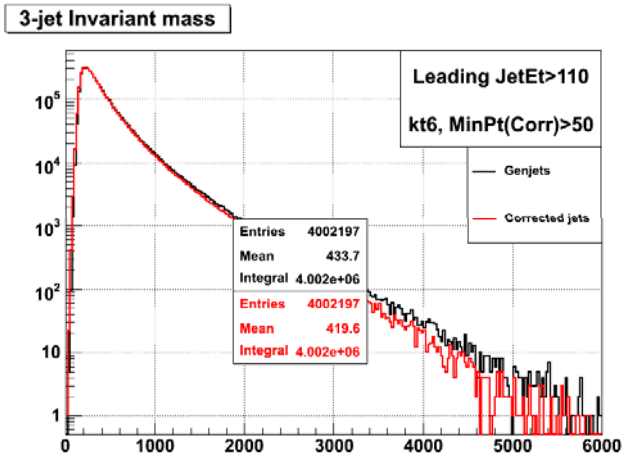
Different topological properties of 3-parton events

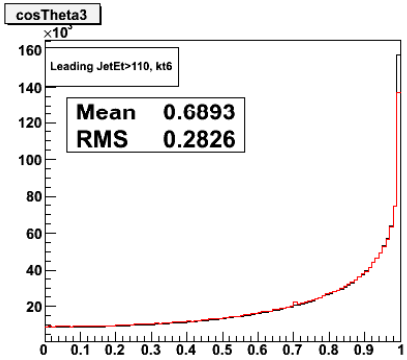
$1+2 \rightarrow 3+4+5$

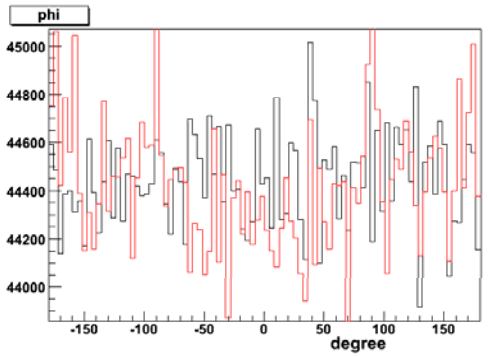




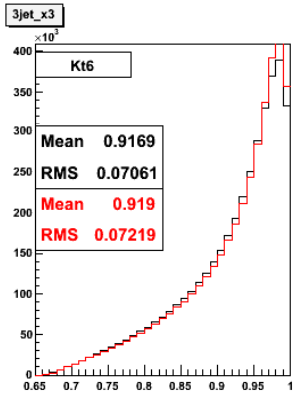
3-jet

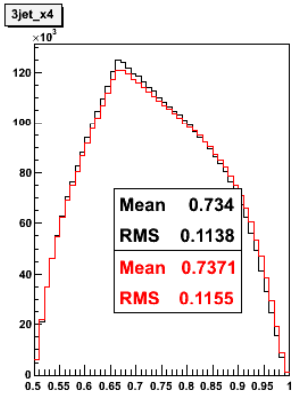


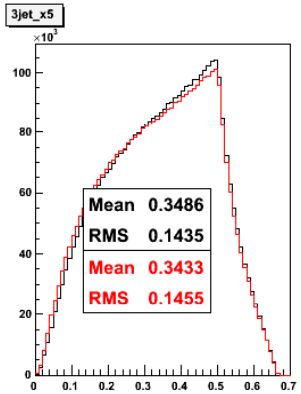




Scaled energies of 3-jet events (x3,x4,x5)







- Cosine of angle w.r.t beam ($\cos\theta_3$) of parton 3.
- Azimuthal angle

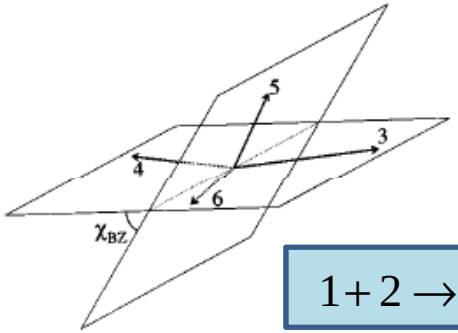
$$x_3, x_5, \cos\theta_3, \psi^*$$

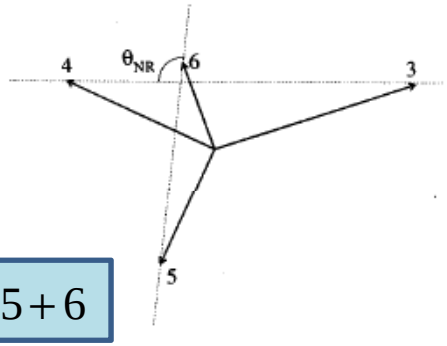
Scaled energies: ordered in their c.o.m. frame

$$x_i = 2E_i / \sqrt{\hat{s}} \qquad x_3 + x_4 + x_5 = 2$$

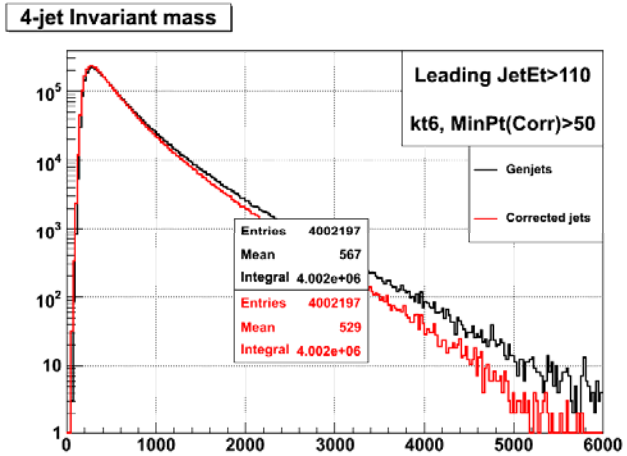
Comparison of GenJets (▬) and Corrected(L2L3) Calojets (▬)

Different topological properties of 4-parton events

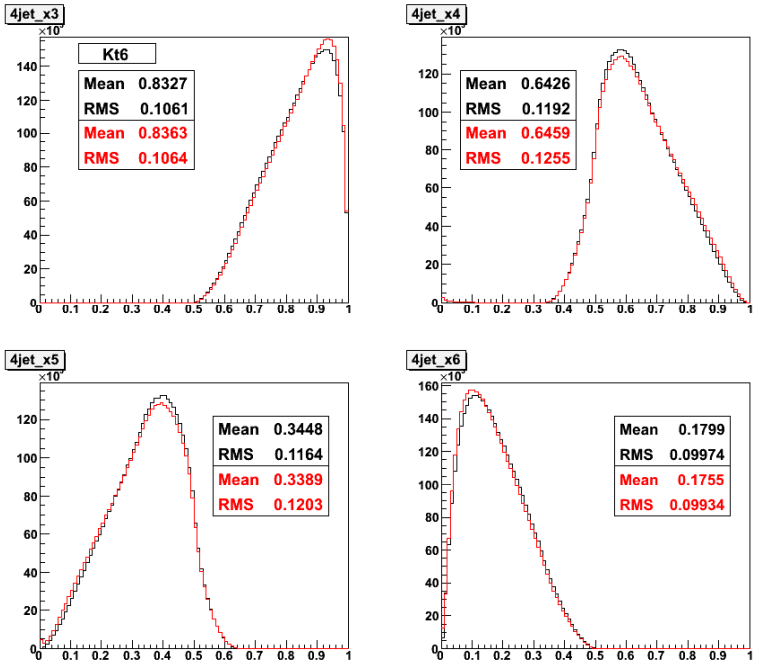


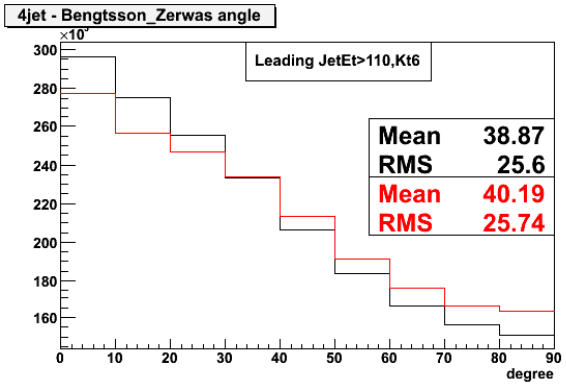


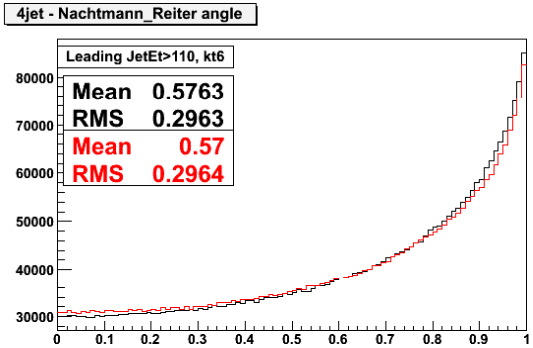
$$1+2 \rightarrow 3+4+5+6$$



Scaled energies of 4-jet events







Bengtsson-Zerwas angle

$$\cos\chi_{BZ} = \frac{(\vec{p}_3 \times \vec{p}_4)\cdot(\vec{p}_5 \times \vec{p}_6)}{|\vec{p}_3 \times \vec{p}_4||\vec{p}_5 \times \vec{p}_6|}$$

Nachtmann-Reiter angle

$$\cos\theta_{NR} = \frac{(\vec{p}_3 - \vec{p}_4)\cdot(\vec{p}_5 - \vec{p}_6)}{|\vec{p}_3 - \vec{p}_4||\vec{p}_5 - \vec{p}_6|}$$

Scaled energies: ordered in their c.o.m. frame: $x_i = 2E_i / \sqrt{\hat{s}}$

$$x_i, \cos\theta_i, \omega_{jk}, \cos\chi_{BZ}, \cos\theta_{NR}$$

Detector Effects

Jet Energy Resolution
Jet Position: η Resolution
Jet Position: Φ Resolution

Jet Energy Resolution

- A gaussian smearing is applied on the generator level momenta to evaluate the effect of the jet energy resolution:

- In the barrel region |η| <1.4

$$\frac{\sigma(p_{\mathrm{T}})}{p_{\mathrm{T}}} = \sqrt{\left(\frac{6.0}{p_{\mathrm{T}}}\right)^2 + \left(\frac{1.4}{\sqrt{p_{\mathrm{T}}}}\right)^2 + (0.043)^2}$$

- In endcap 1.4 < |η| <3.0

$$\frac{\sigma(p_{\mathrm{T}})}{p_{\mathrm{T}}} = \sqrt{\left(\frac{6.6}{p_{\mathrm{T}}}\right)^2 + \left(\frac{1.1}{\sqrt{p_{\mathrm{T}}}}\right)^2 + (0.044)^2}$$

the functions were derived from MC over CSA08 JetEtxx samples

https://twiki.cern.ch/twiki/bin/view/CMS/CSA08AnaJets

- Define observed differences as systematic uncertainties

Position (η/ Φ) Resolution

- A gaussian smearing is applied on the jet position resolution in η
- in the barrel region |η| <1.4:

$$\sigma(\eta) = \sqrt{\left(\frac{1.31}{p_{\mathrm{T}}}\right)^2 + \left(\frac{0.25}{\sqrt{p_{\mathrm{T}}}}\right)^2 + (0.026)^2}$$

- In the endcap 1.4 < |η| < 3.0 and HF 3.0 < |η| < 5.0 regions

$$\sigma(\eta) = \sqrt{\left(\frac{1.42}{p_{\mathrm{T}}}\right)^2 + \left(\frac{0.21}{\sqrt{p_{\mathrm{T}}}}\right)^2 + (0.017)^2}$$

$$\sigma(\eta) = \sqrt{\left(\frac{1.25}{p_{\mathrm{T}}}\right)^2 + (0.025)^2}$$

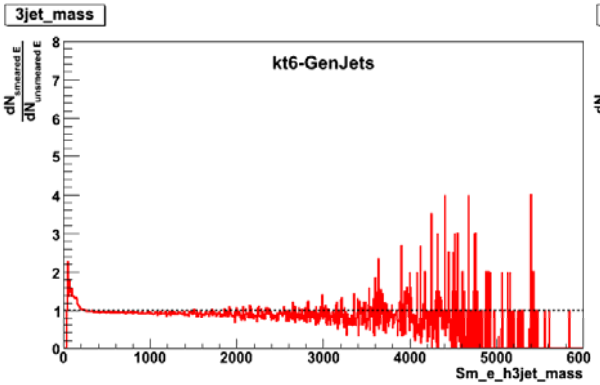
- A gaussian smearing is applied on the jet position resolution in ϕ in the barrel region |η| <1.4:

$$\sigma(\phi) = \sqrt{\left(\frac{2.72}{p_{\mathrm{T}}}\right)^2 + \left(\frac{0.23}{\sqrt{p_{\mathrm{T}}}}\right)^2 + (0.004)^2}$$

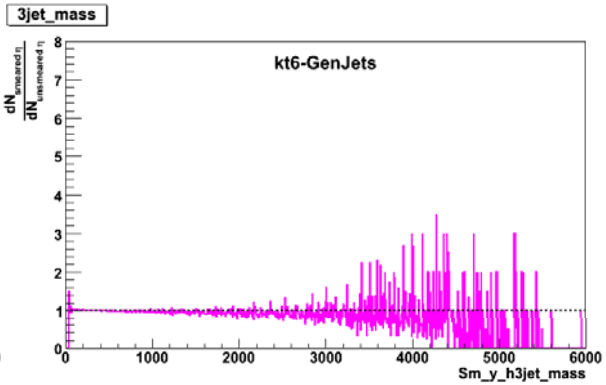
- Define observed differences as systematic uncertainties

[These functions were derived by Zhen Qi from MC over CSA07 PYTHIA QCD-samples in the Gumbo soup]

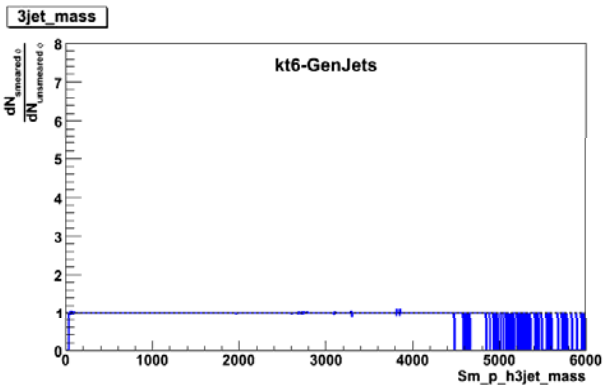
Jet Energy & Position Resolution : 3-jet invariant mass



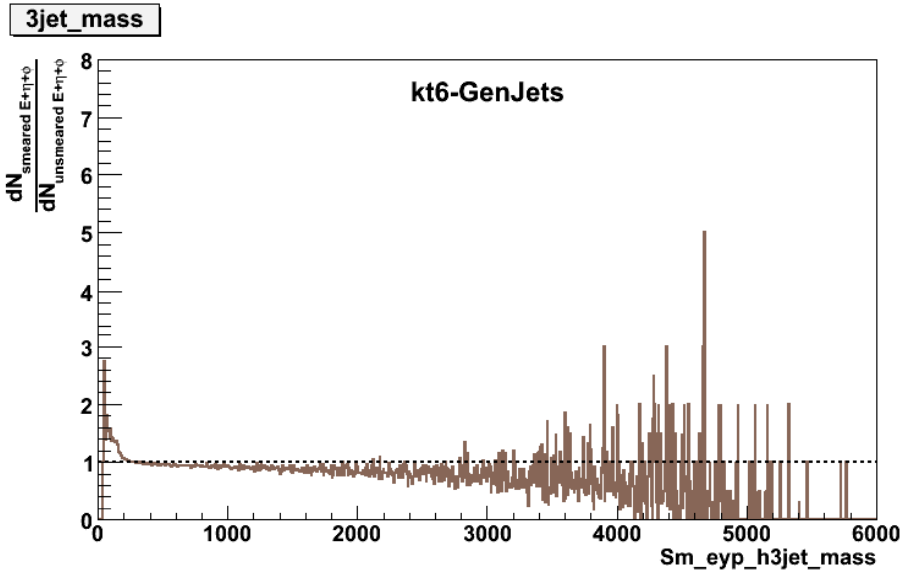
Energy smearing



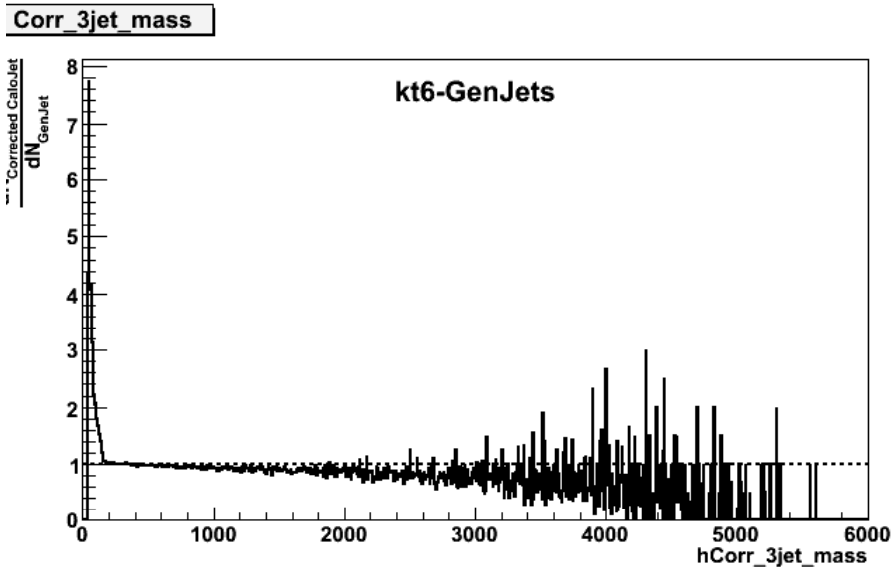
Eta smearing



Phi smearing

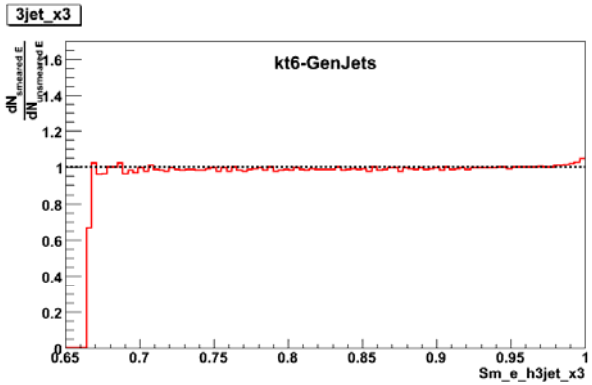


Energy+Eta+Phi smearing

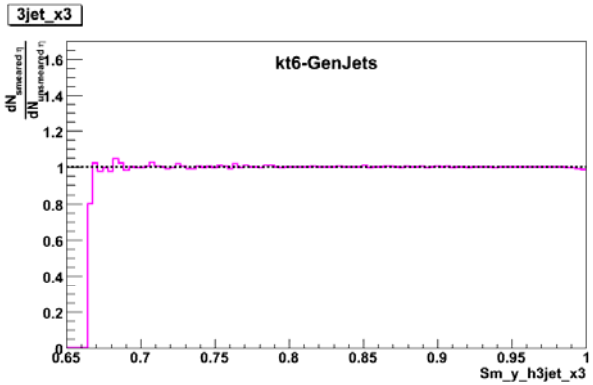


Corrected Calo/Genjet

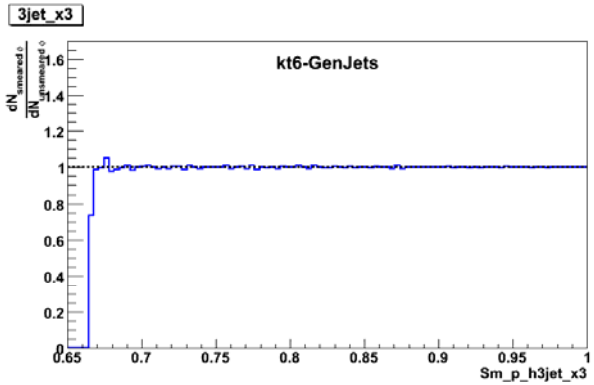
Jet Energy & Position Resolution : Scaled energy (x3) of 3-jet



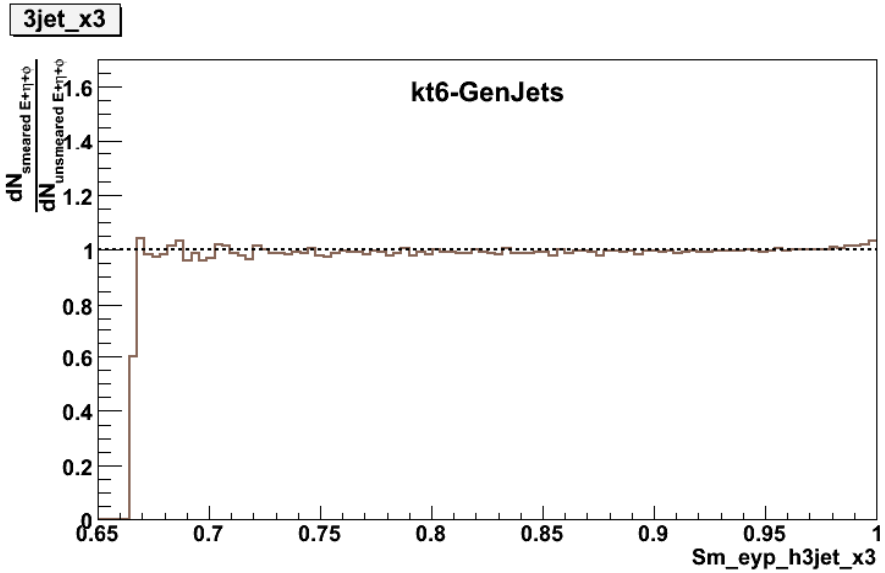
Energy smearing



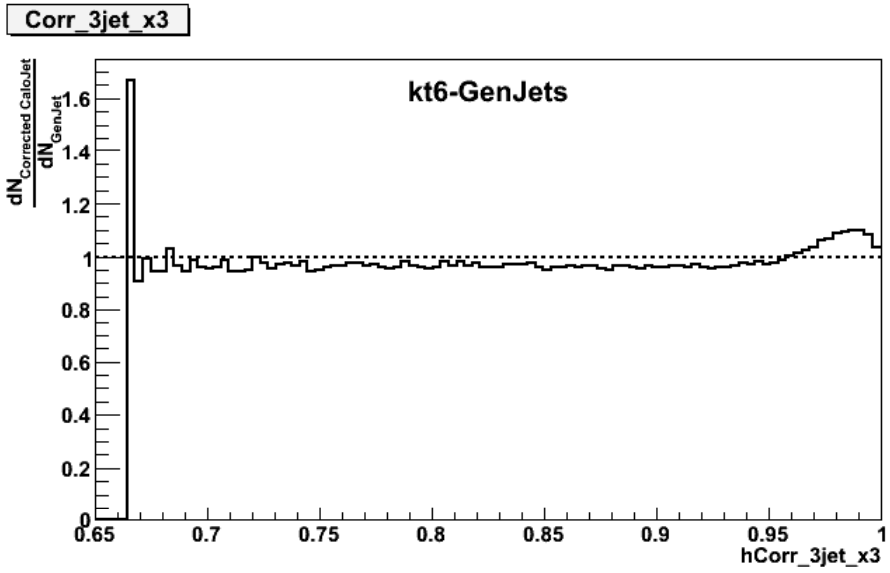
Eta smearing



Phi smearing

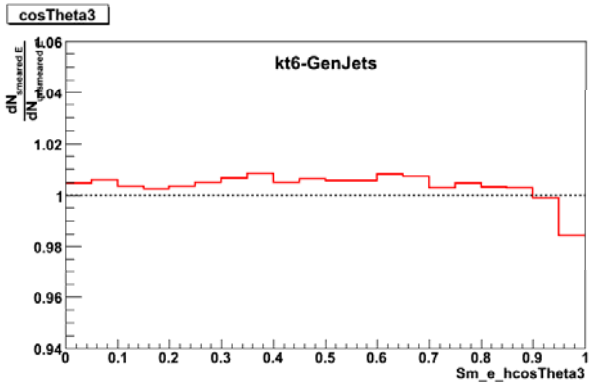


Energy+Eta+Phi smearing

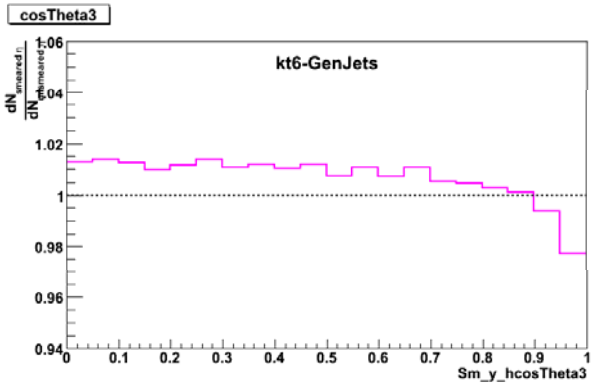


Corrected Calo/Genjet

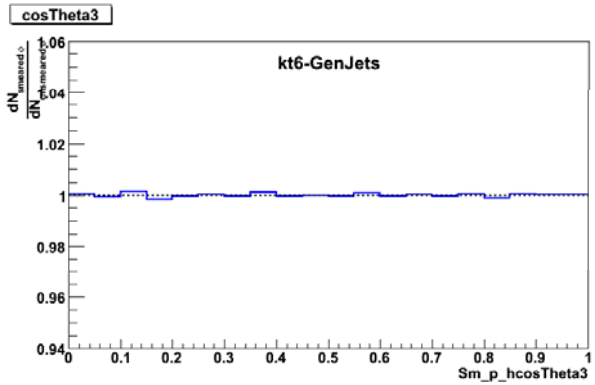
Jet Energy & Position Resolution : 3-jet $\cos\theta_3$



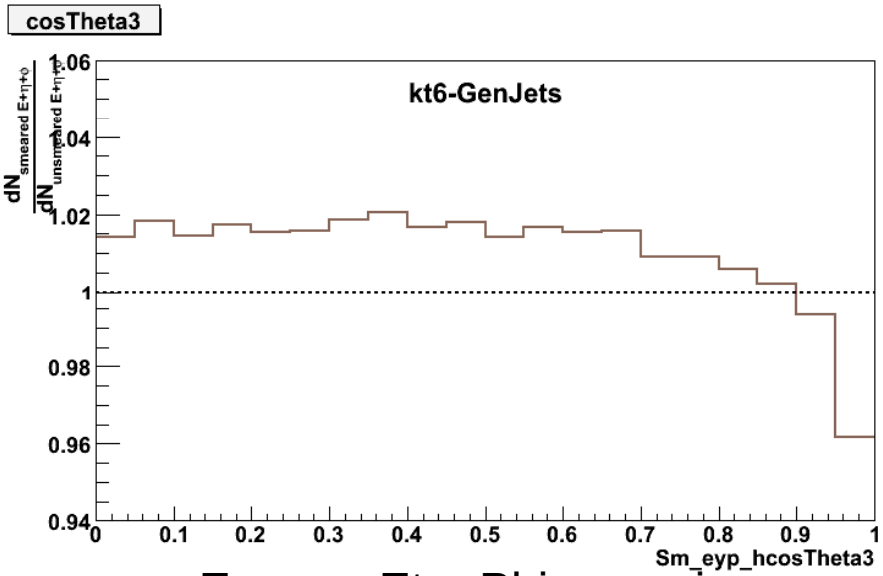
Energy smearing



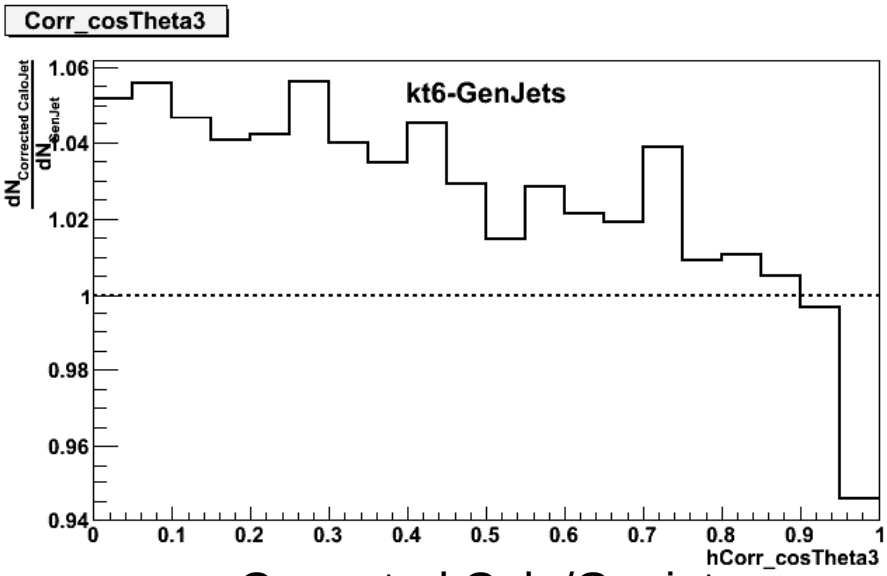
Eta smearing



Phi smearing

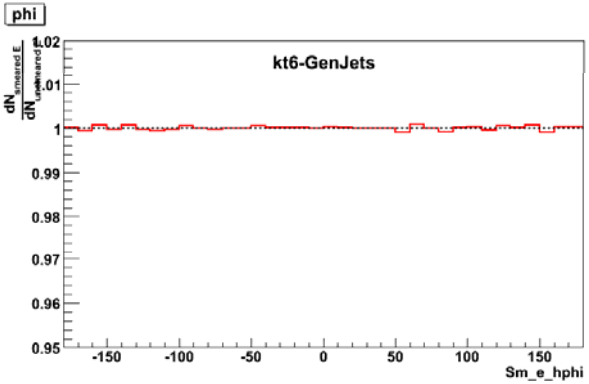


Energy+Eta+Phi smearing

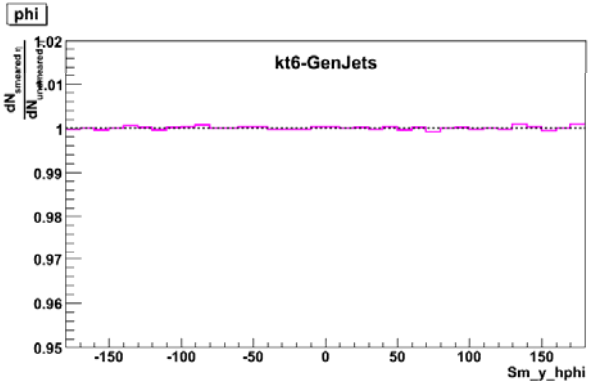


Corrected Calo/Genjet

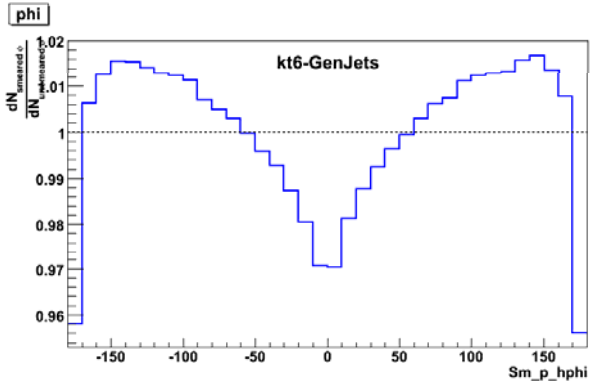
Jet Energy & Position Resolution : 3-jet azimuthal angle (Φ)



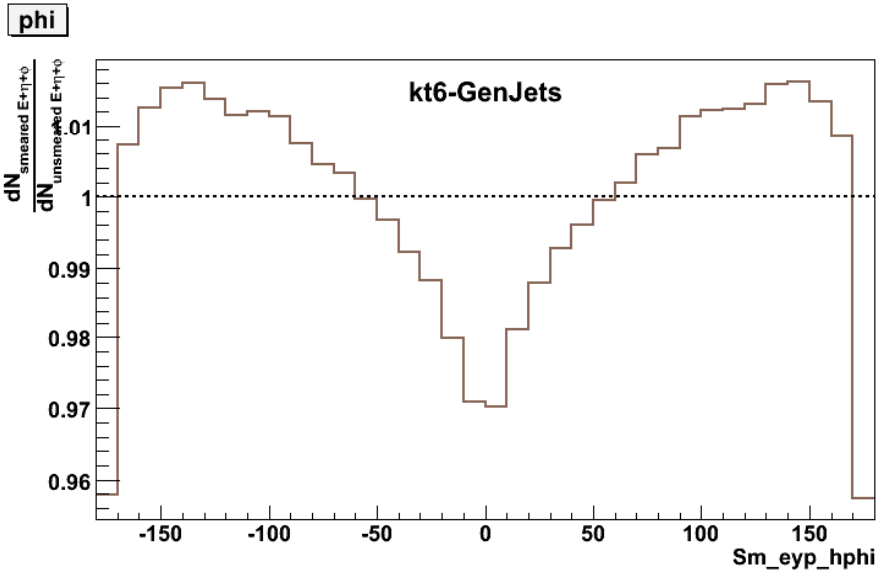
Energy smearing



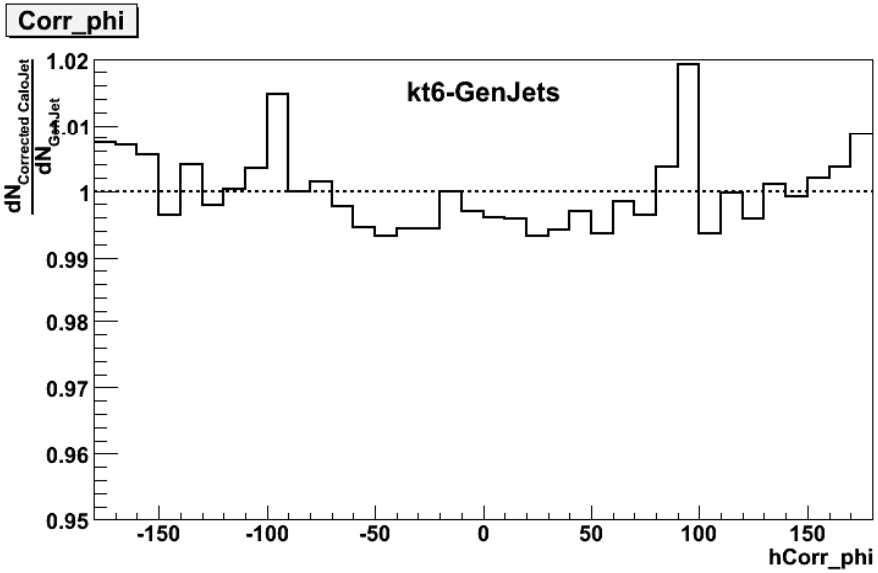
Eta smearing



Phi smearing

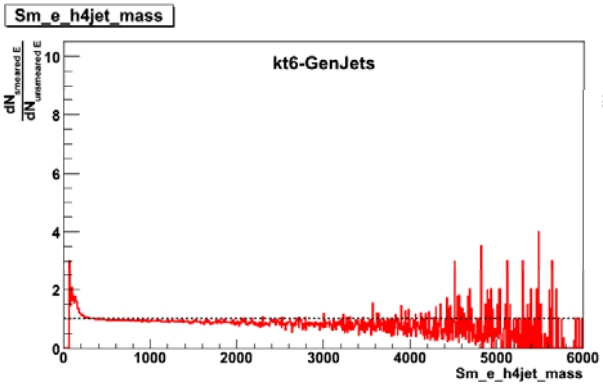


Energy+Eta+Phi smearing

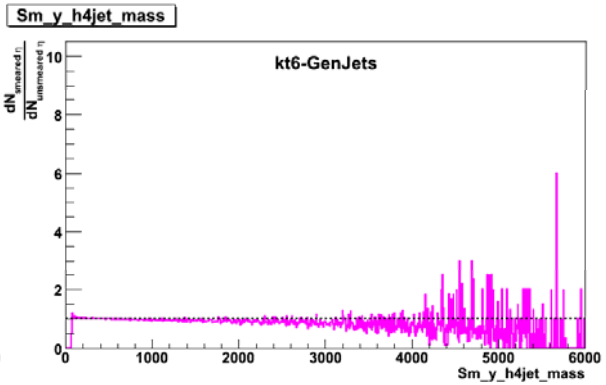


Corrected Calo/Genjet

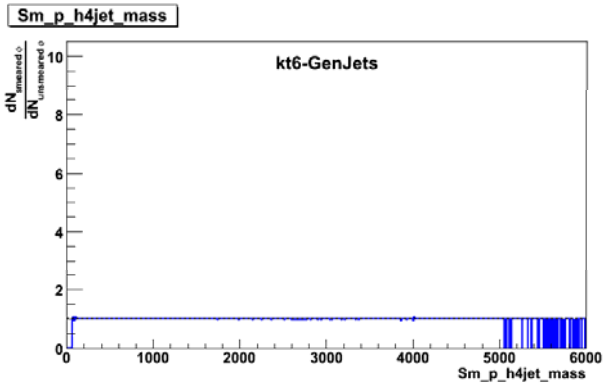
Jet Energy & Position Resolution : 4-jet invariant mass



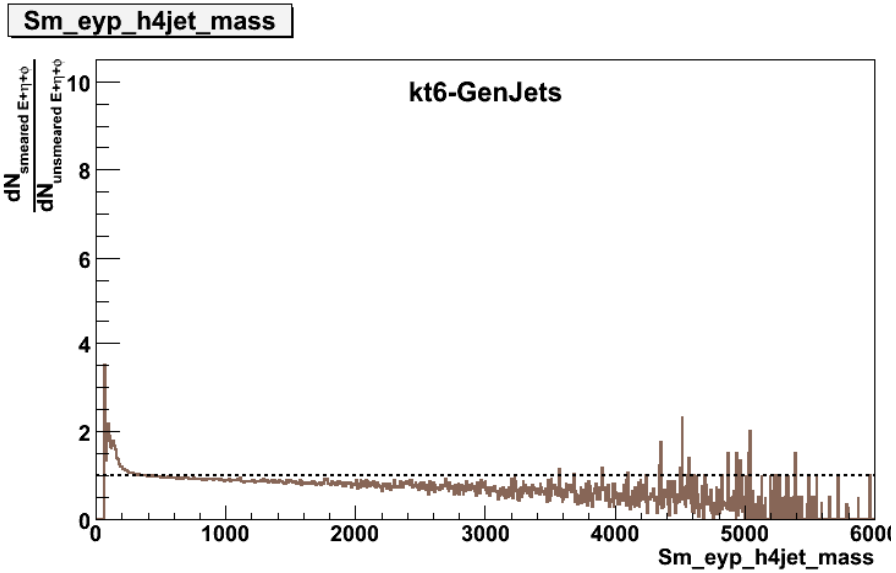
Energy smearing



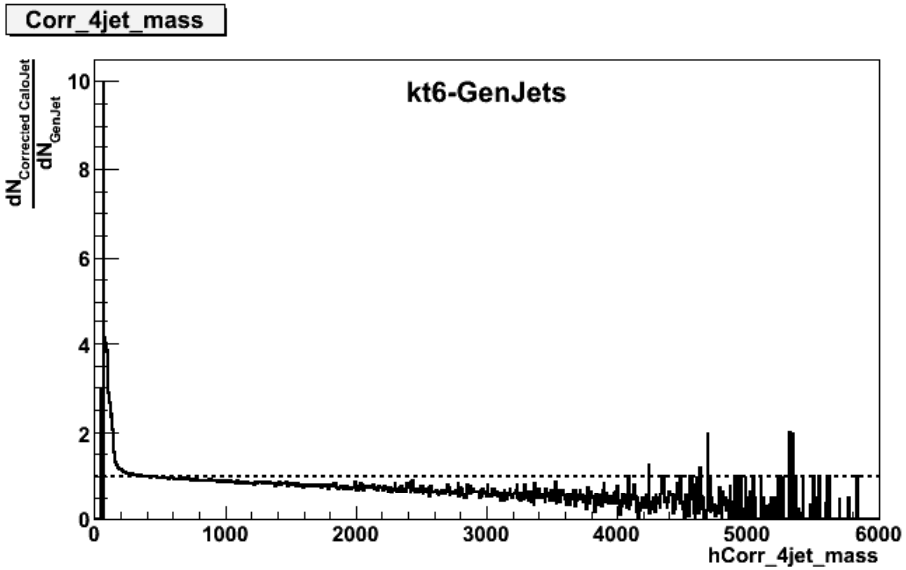
Eta smearing



Phi smearing

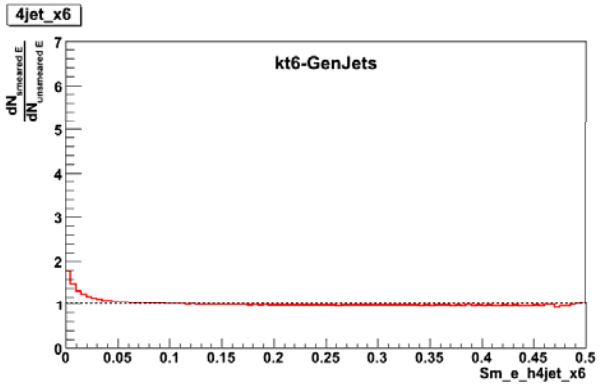


Energy+Eta+Phi smearing

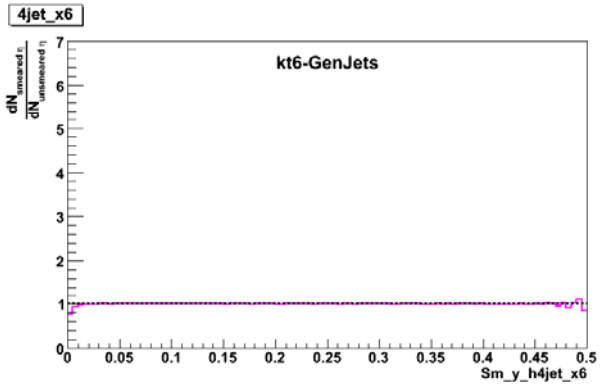


Corrected Calo/Genjet

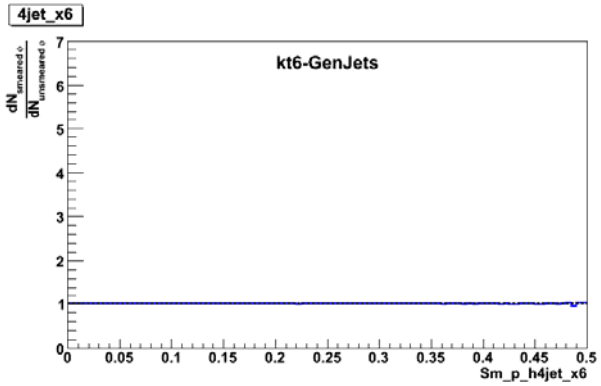
Jet Energy & Position Resolution : Scaled energy (x6) of 4-jet



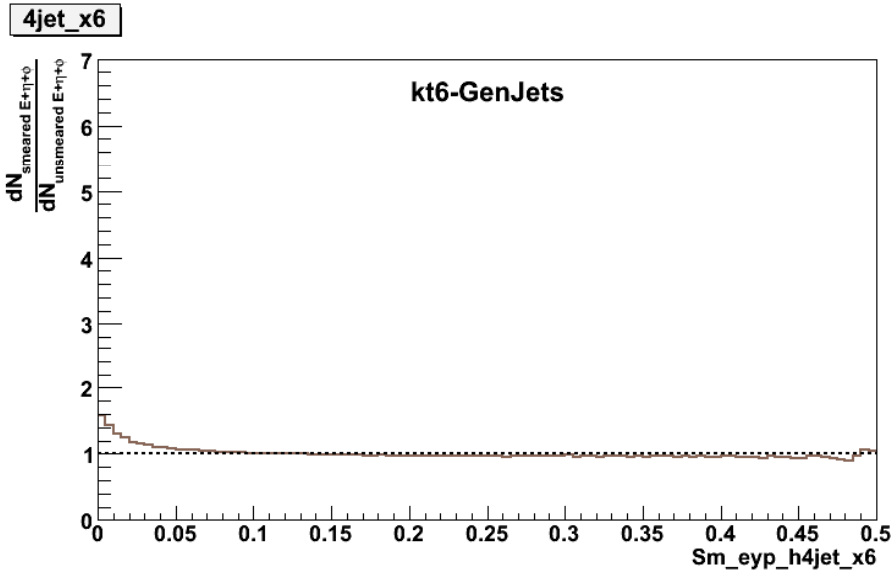
Energy smearing



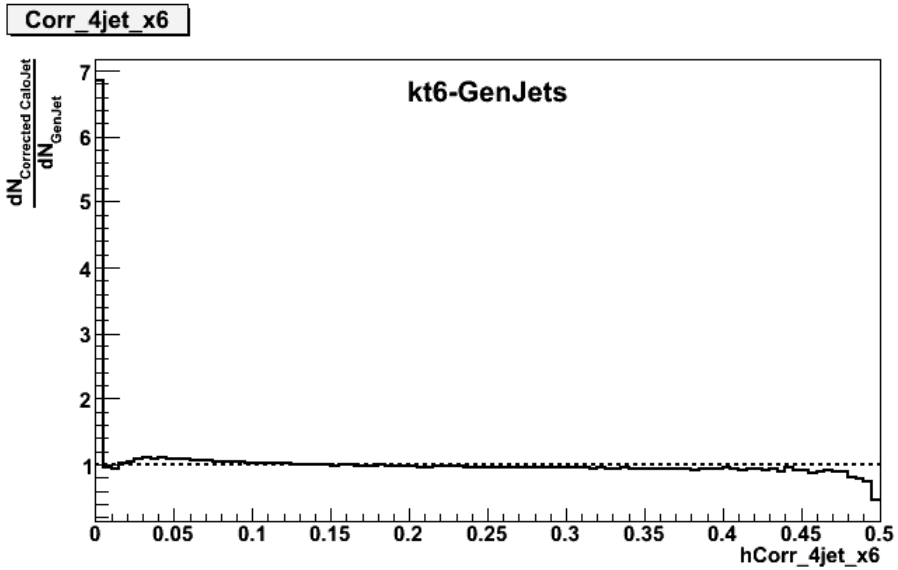
Eta smearing



Phi smearing

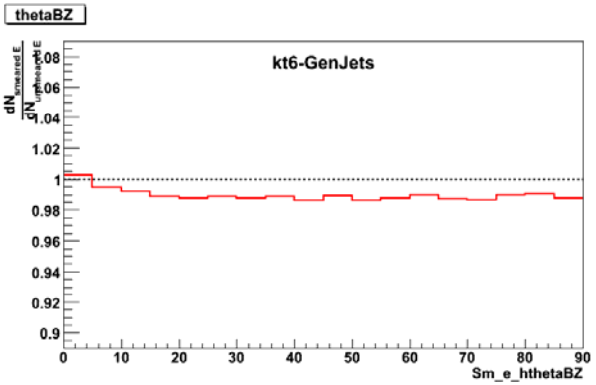


Energy+Eta+Phi smearing

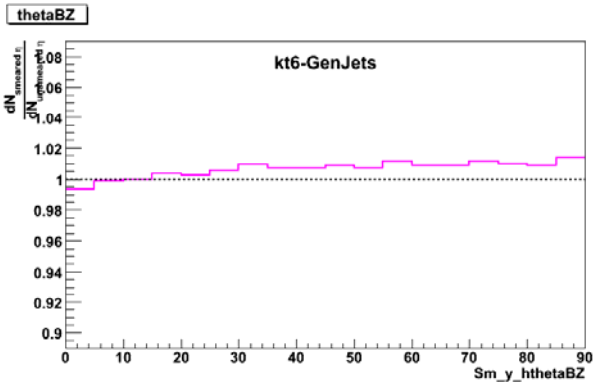


Corrected Calo/Genjet

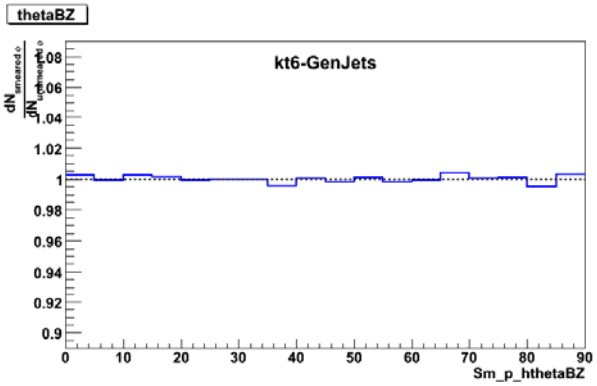
Jet Energy & Position Resolution : Bengtsson-Zerwas angle (4-jet)



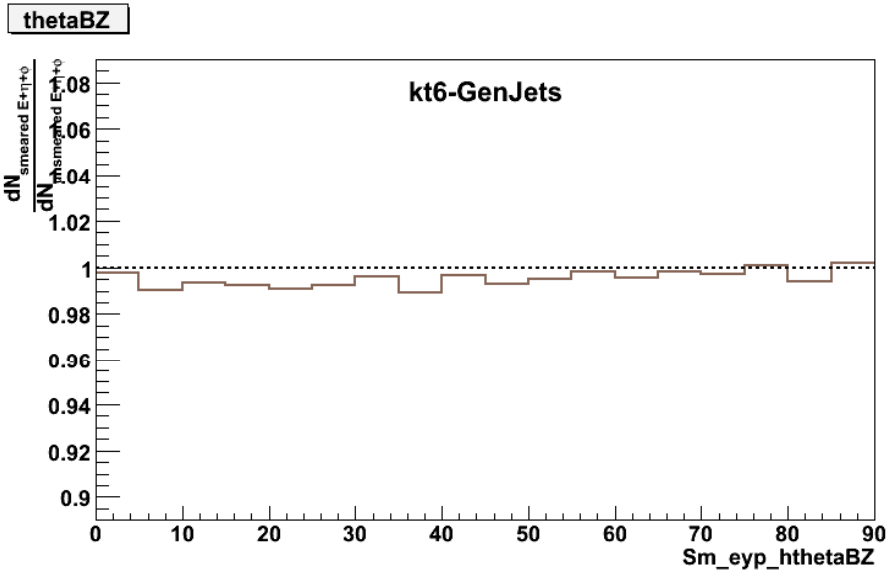
Energy smearing



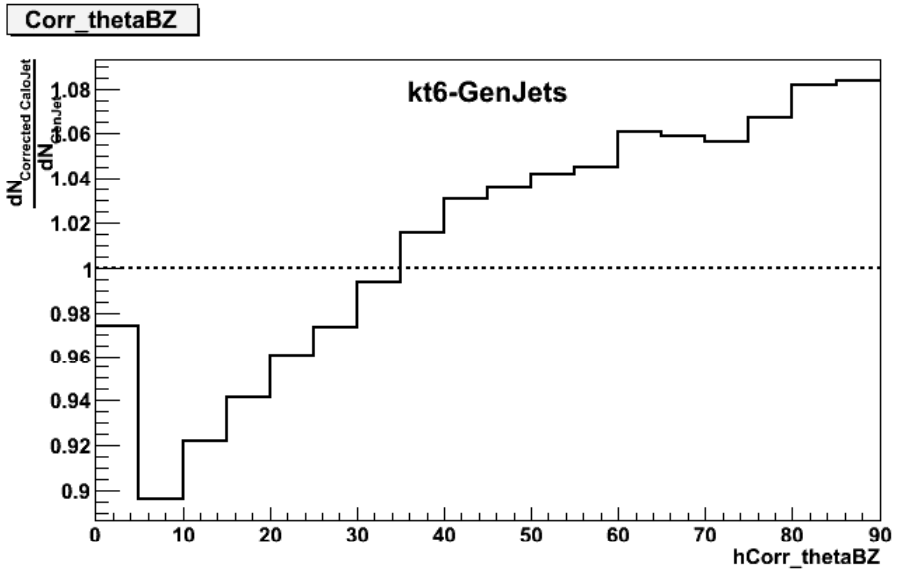
Eta smearing



Phi smearing

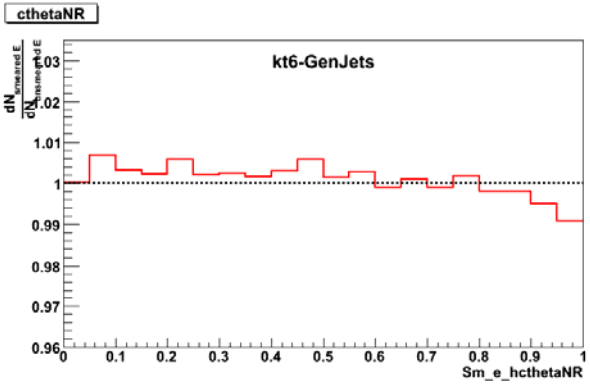


Energy+Eta+Phi smearing

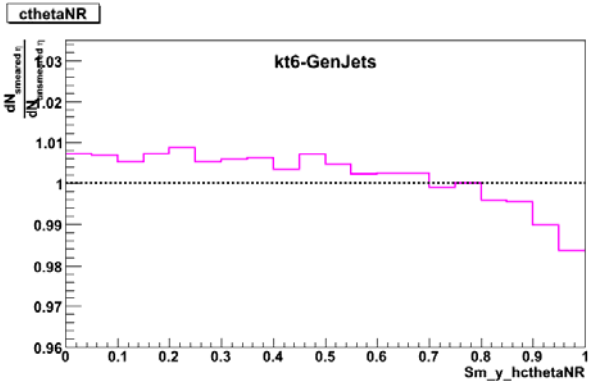


Corrected Calo/Genjet

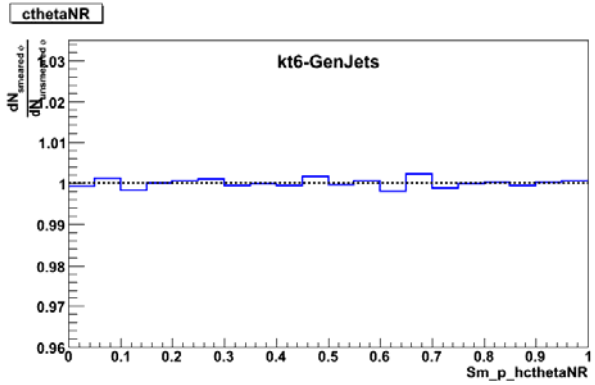
Jet Energy & Position Resolution : Nachtmann-Reiter angle (4-jet)



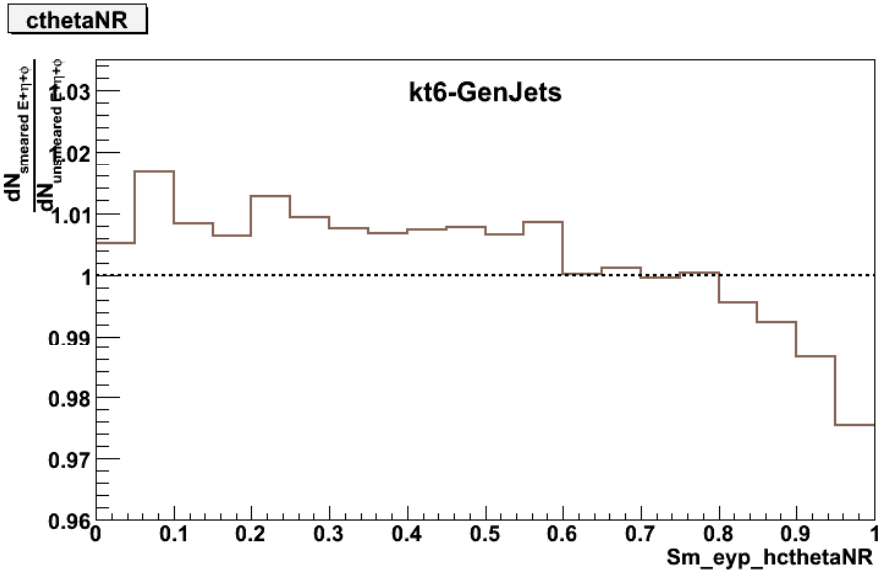
Energy smearing



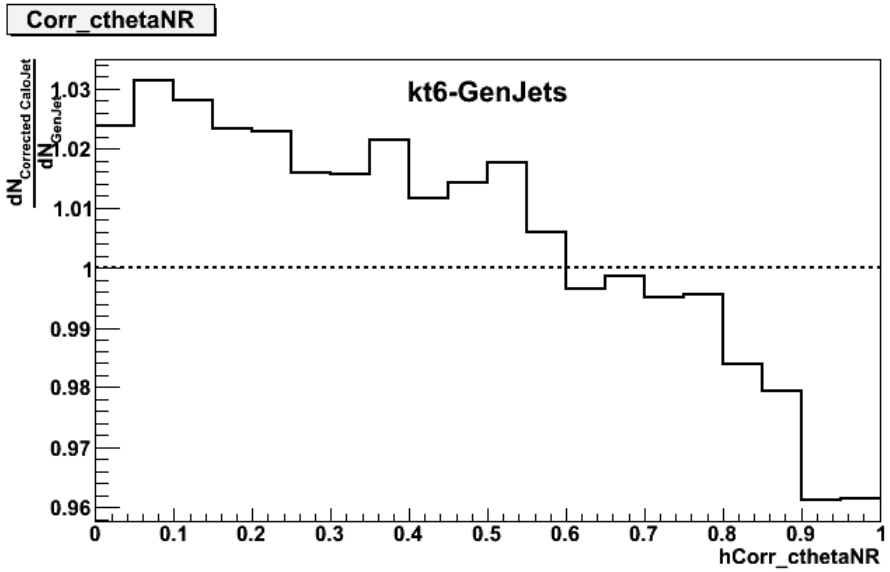
Eta smearing



Phi smearing



Energy+Eta+Phi smearing



Corrected Calo/Genjet

Summary and Future Plans

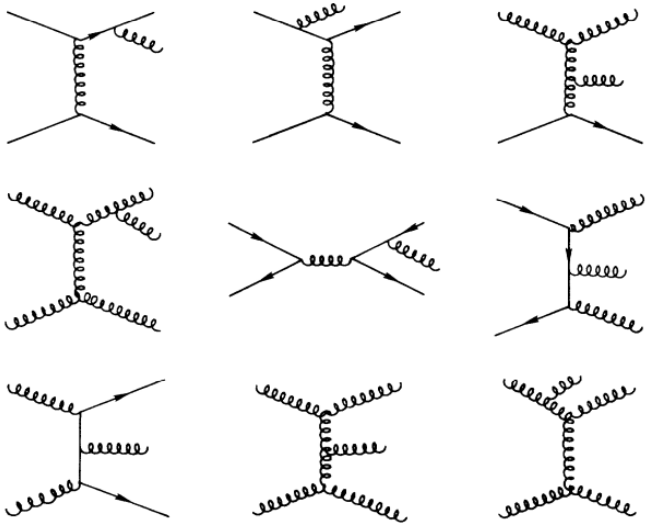
1. From the CSA08 QCD MC samples one specific trigger sample (JetEt50) is studied for *Fastjet* (Kt6) algorithm.
2. Detector effects, namely, jet energy and position resolutions in η and φ are presented.
3. Combined effect of the resolutions on the angular variables are small.
4. Comparison of Pythia Monte Carlo sample with Matrix Elements calculations (eg. ALPGEN) are under way. A single CSA08 sample having a large bias makes the comparison harder. Analysis will be redone with the Summer08 samples.
5. Have to try different QCD models (like Phase Space, switch off triple gluon vertex, change gluon spin, alternate to inside generator).

❖ Special thanks to Konstantinos Kousouris for useful discussions.

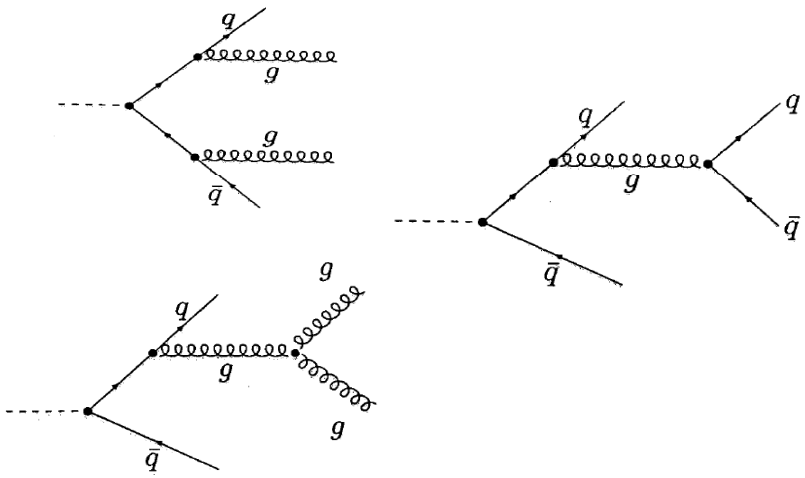
Back up slides

Multijet Study

❑ The essential features of QCD are provided by the vector nature of gluon gluon self coupling. These reflect on the so called colour factors which appear in various vertices.



3-parton final states



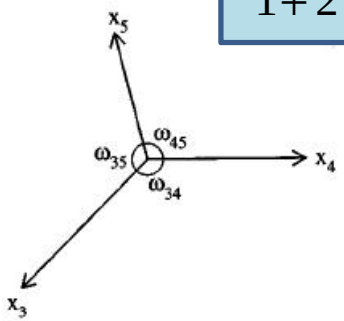
4-parton final states

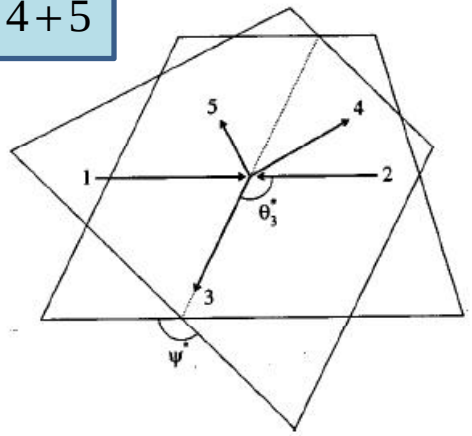
❑ Several tests of QCD which are sensitive to the gluon self-coupling have already been carried out in the earlier e^+e^- and hadron collider experiments which are based on study of angular correlations in 3-jet and 4-jet events.

❑ Study of thee and four jet events allows a test of the validity of the QCD calculations to higher order and a probe of the underlying QCD dynamics. The topological distributions of these multijet events provide sensitive tests of the QCD matrix element calculations.

Different topological properties of 3-parton events

$$1+2 \rightarrow 3+4+5$$





3-jet

- Scaled energies: ordered in their c.m. frame:

$x_i = 2E_i / \sqrt{\hat{s}}$ where $x_3 + x_4 + x_5 = 2$

Alternately, $$x_i = \frac{2\sin\omega_{jk}}{\sin\omega_{34} + \sin\omega_{45} + \sin\omega_{53}}$$

- Scaled invariant masses of jet pairs:

$$\mu_{ij} = m_{ij} / \sqrt{\hat{s}} : i, j = 3,4,5; i \neq j$$

- Angles that fix the event orientation
Cosine of angle w.r.t beam ($\cos\theta_3$)
of parton 3.

- Azimuthal angle of parton 3 (φ_3).

- Angle between the plane containing partons 1 and 3 and the plane containing partons 4 and 5 (ψ^*) defined by

$$\cos\psi^* = \frac{(\vec{p}_1 \times \vec{p}_3)\cdot(\vec{p}_4 \times \vec{p}_5)}{|\vec{p}_1 \times \vec{p}_3||\vec{p}_4 \times \vec{p}_5|}$$

- The Ellis-Karliner angle, λ, is defined as:

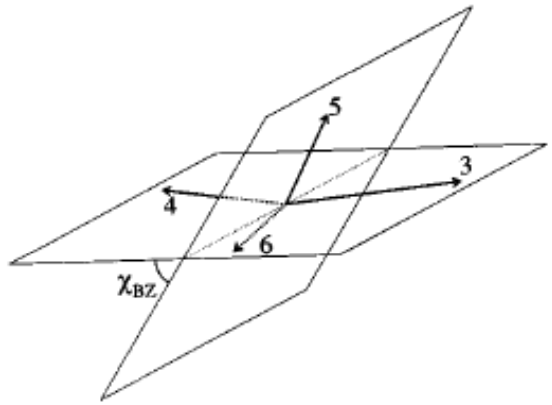
$$|\cos\lambda| = \frac{\sin\omega_{45} - \sin\omega_{53}}{\sin\omega_{34}}$$

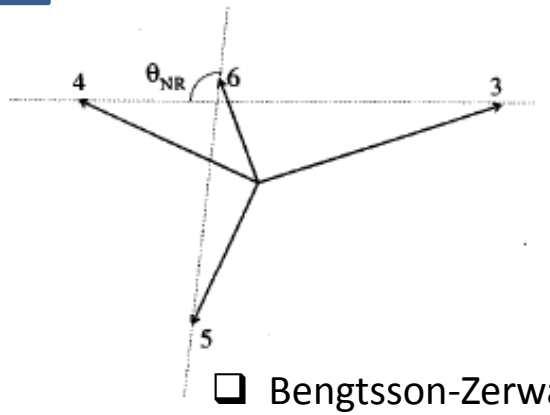
A set of kinematic variables for 3-parton:

$$x_3, x_5, \cos\theta_3, \psi^*, \cos EK$$

Different topological properties of 4-parton events

$$1+2 \rightarrow 3+4+5+6$$





- Scaled energies: ordered in their c.o.m. frame:

$$x_i = 2E_i / \sqrt{\hat{s}}$$

- Cosines of the polar angles :

$$\cos\theta_i, i = 3,4,5,6$$

- Cosines of their opening angles :

$$\cos\omega_{ij} : i, j = 3,4,5,6; i \neq j$$

- Scaled masses:

$$\mu_{ij} = m_{ij} / \sqrt{\hat{s}} : i, j = 3,4,5,6; i \neq j$$

- Bengtsson-Zerwas angle :
  Angle between the plane containing the two leading jets and the plane containing the two non-leading jets.

$$\cos\chi_{BZ} = \frac{(\vec{p}_3 \times \vec{p}_4)\cdot(\vec{p}_5 \times \vec{p}_6)}{|\vec{p}_3 \times \vec{p}_4||\vec{p}_5 \times \vec{p}_6|}$$

- Nachtmann-Reiter angle:
  Angle between the momentum vector differences of the leading jets and the two non-leading jets:

$$\cos\theta_{NR} = \frac{(\vec{p}_3 - \vec{p}_4)\cdot(\vec{p}_5 - \vec{p}_6)}{|\vec{p}_3 - \vec{p}_4||\vec{p}_5 - \vec{p}_6|}$$

CSA 08 (S156) data set with cross-sections:

Sample	kT, D=0.6	SISCone, R=0.7	Generator	Events	Xsec [pb]	L[pb-1]
JetET20	6035 ± 452	6370 ± 517	6306	3 926 600	101 600 000	0.0386
JetET30	1210 ± 47	1213 ± 44	1271	4 131 600	21 550 000	0.1917
JetET50	151 ± 2	152 ± 2	151	4 010 400	2 484 000	1.6145
JetET80	26.3 ± 0.4	26.6 ± 0.4	27.3	2 891 200	323 700	8.9317
JetET110	4.98 ± 0.04	4.99 ± 0.04	5.4	3 980 000	88 730	44.8552
JetET150	1	1	1	4 172 400	17 120	243.7150

Each individual JetETxx sample is treated like a primary dataset based on a single jet trigger.

As these datasets are highly biased by construction we have decided to take one MC sample and apply HLT cuts to decide the kinematic range where the sample is fully efficient.

Sample	p_T Min (GeV)	Events
JetET20	30	3.926.600
JetET30	45	4.131.600
JetET50	75	4.010.400
JetET80	120	2.891.200
JetET110	160	3.980.000
JetET150	220	4.171.600
GammaJets	10	1.461.256