Study of jet transverse structure with CMS experiment at 10 TeV

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for the CMS collaboration

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Outline

1. Introduction
2. CMS jet transverse structure variables
3. Monte Carlo predictions
4. CMS experiment
5. Jet transverse structure reconstructed from calorimetric data
6. Jet transverse structure measured with charged particles
7. Predictions of different generators: PYTHIA and HERWIG++
8. Estimation of the quark jet fraction
9. Conclusions

Introduction

- Jet internal structure is sensitive to the type of jet inducing parton (quark/gluon) and p_T^{jet}

- The study is a good test of different models of parton cascades and hadronization

- The study is important for early CMS analysis:
  - MC generators tuning
  - validation of detector simulation
  - validation of jet reconstruction

- Jet shapes have been already studied at LEPI, HERA, CDF, D0

With the variables based on the fraction of jet transverse momentum collected in an inner subcone inside the jet

- For CMS we use the new variables that doesn't depend on the choice of the subcone radius

Phys.Rev.Lett. 69, 3615 (1992), Phys.Rev. D 44, 7(1991);CDF Collaboration, Phys.Rev. D71, 112002 (2005).; DØ Collaboration, Phys. Lett. B357, 500508 (1995); ZEUS Collaboration, The Eur.Phys.Journal C 2, 1 61-75 (1998); LEP1: OPAL Collaboration, R. Akers et al., Zeit.f.Phys. C 63, 197 (1994).

CMS jet transverse structure variables

We study jet transverse structure with **the second moment of jet profile in transverse momentum:**

$$< \delta R^2_{jet} > (p_T) = \frac{\sum_{i \in jet} \Delta R^2 (i, jet) \cdot p_T{}^i}{\sum_{i \in jet} p_T^i}$$

and

$$< \delta \eta^2_{jet} > (p_T) = \frac{\sum_{i \in jet} (\eta_{jet} - \eta_i)^2 \cdot p_T{}^i}{\sum_{i \in jet} p_T^i}$$

$$< \delta \phi^2_{jet} > (p_T) = \frac{\sum_{i \in jet} (\phi_{jet} - \phi_i)^2 \cdot p_T{}^i}{\sum_{i \in jet} p_T^i}$$

In this way: $< \delta R^2 > = < \delta \phi^2 > + < \delta \eta^2 >$

Summation is over: stable particles or calorimeter towers or reconstructed tracks

CMS Jet transverse structure variables

Because of the angular smearing of the calorimeter jet relative to the generator jet, $<\delta R^2_{jet}>$ is calculated with respect to different axes.

To avoid the impact of jet angular resolution one can use 2nd central moments of η and ϕ Instead of 2nd moments:

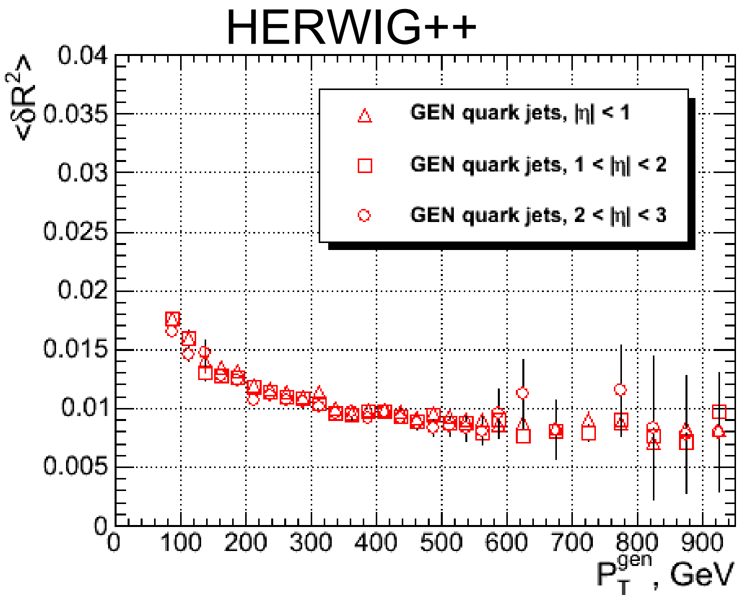
$$<\delta\varphi_c^2> = <\delta\varphi^2> - <\delta\varphi>^2$$

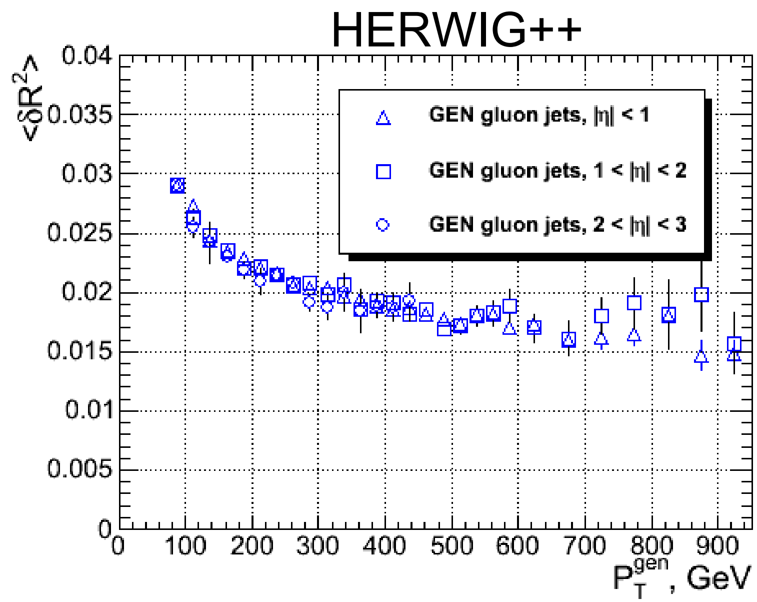
$$<\delta\eta_c^2> = <\delta\eta^2> - <\delta\eta>^2$$

And the trace of $\eta-\phi$ correlation matrix:

$$<\delta R_c^2> = <\delta\varphi_c^2> + <\delta\eta_c^2>$$

Monte Carlo predictions

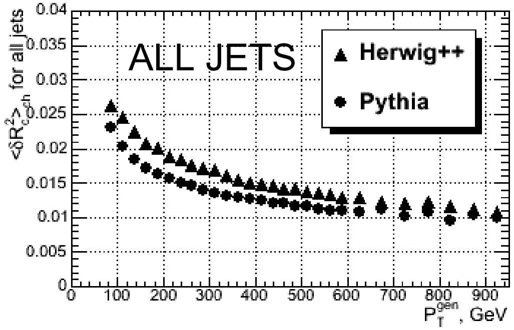


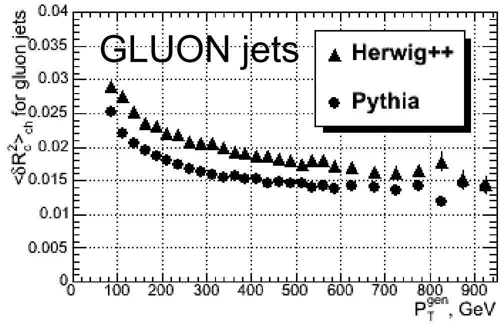


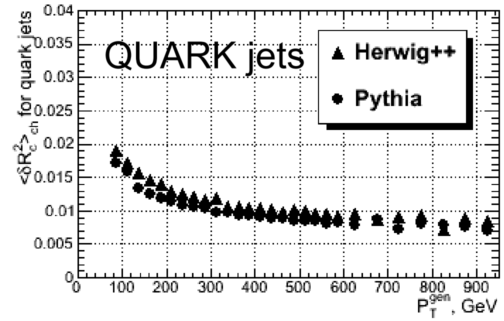
Both HERWIG++ and PYTHIA generators:

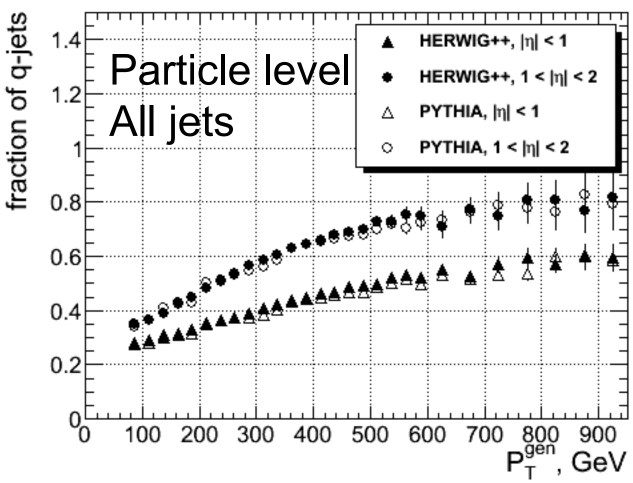
- ✓ δR^2 depends on p_T
- ✓ MC predicts no dependence of δR^2 on η both gluon and quark jets
- ✓ The same behaviour for $< \delta R_c^2 >$ and $< \delta R^2 >$

Monte Carlo predictions





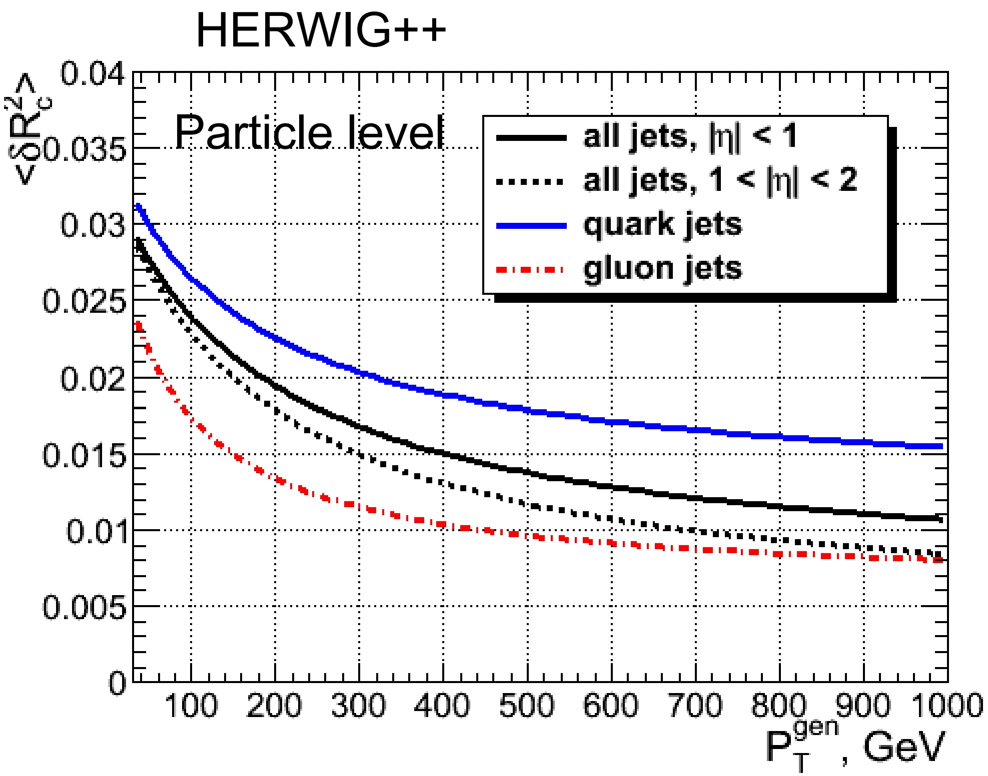




The difference in the prediction for jet shapes between PYTHIA and HERWIG++ is due to the different models for gluon jet hadronization

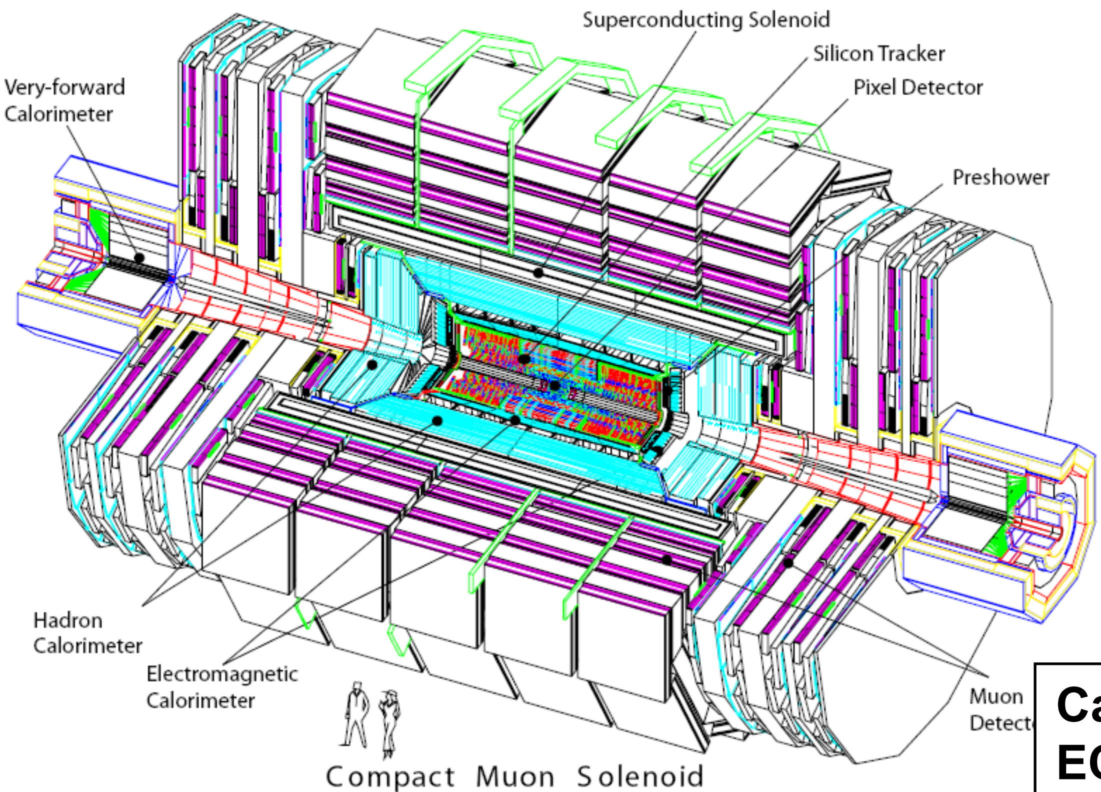
Both HERWIG++ and PYTHIA predict nearly the same q-jets fraction for the same jet p_T and η.

Monte Carlo predictions



Jet transverse structure for all jets (black lines) depends on η while it does not depend on η for gluon and quark jets.
This is due to different quark/gluon jets fraction in the rapidity regions

Jet transverse structure with CMS experiment



Weight 14000t
Diameter 15m
Length 21.6m
Magnetic field 3.8T

Tracker:
Silicon Microstrips:
10 barrel layers,
3+9 fw disks, tot 200m^2
Pixels:
3 barrel layers,
2 fw disks

Calorimeters:
ECAL barrel&endcap:
Scintillating $PbWO_4$ crystals
HCAL
Plastic scintillator

Jet transverse structure reconstructed from calorimetric data

δR^2_{cal} – jet transverse structure calculated from towers formed by ECAL+HCAL calorimeter

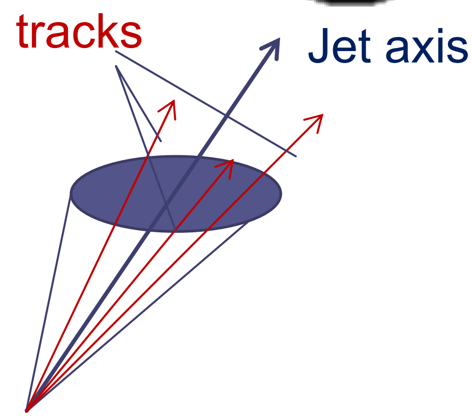
Sources of detector related bias:

- the strong magnetic field of the CMS solenoid
- non-linear and non-uniform calorimeter response to hadrons
- hadron shower and calorimeter tower transverse sizes

✓Iterative Cone algorithm (R=0.5) - for jets reconstruction

✓ JPT - JetPlusTrack algorithm for jet energy calculation (CMS PAS JME-09-002 (2009))

Jet transverse structure measured with charged particles



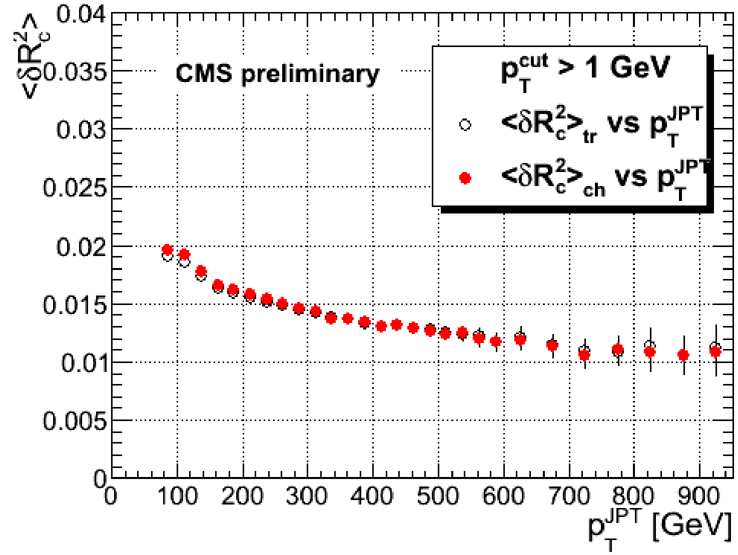
To avoid the magnetic field bias and bias due to calorimeter energy reconstruction we analyze the charged component shape of jets

δR^2_{tr} – jet transverse structure calculated from tracks (reconstructed in CMS tracker)
δR^2_{ch} – jet transverse structure calculated from charged particles (generated by MC generator)

We restrict our study to

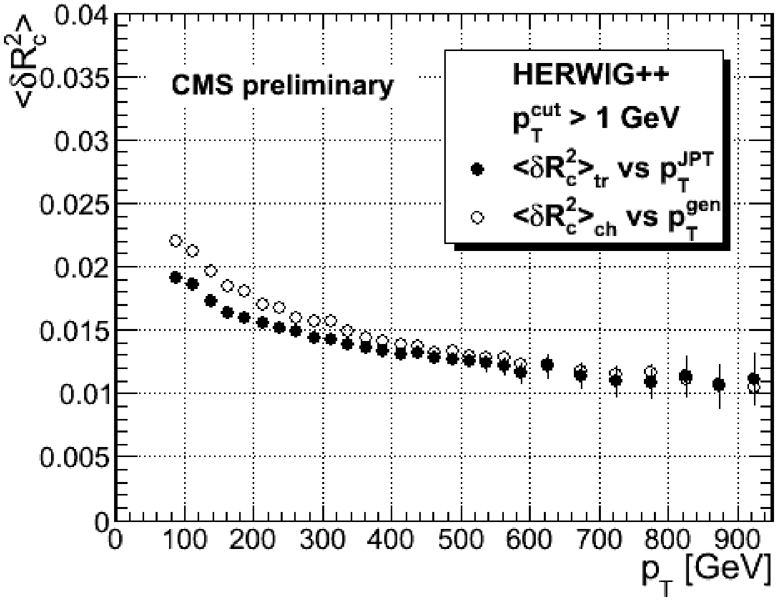
✓ $|\eta| < 1$, where the fake rate of the reconstructed tracks will be less than 2%

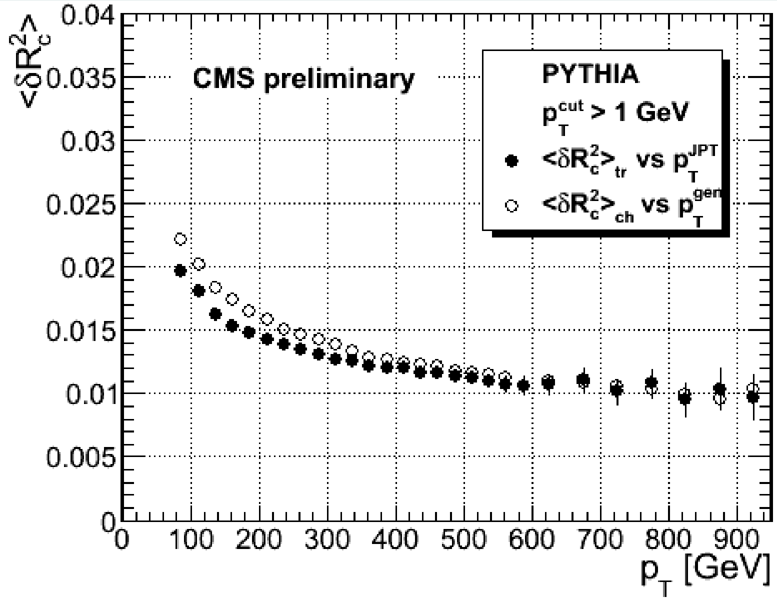
✓ $p_T > 1$ GeV, where the track reconstruction efficiency does not depend on track momentum



Predictions of different generators: PYTHIA and HERWIG++

The comparison of generator level and reco objects for HERWIG++ and PYTHIA: $<\delta R^2_c>_{tr}(P_T^{corr})$ and $<\delta R^2_c>_{ch}(P_T^{gen})$

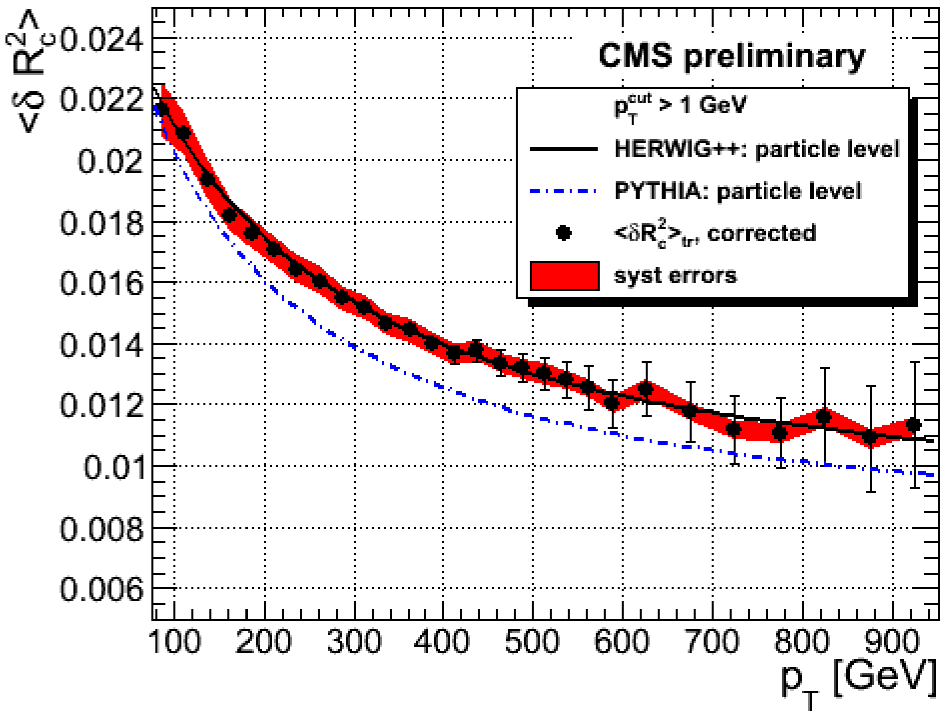




✓The average value of the biases was calculated and applied like correction to "data" points

✓ Half of the difference was incorporated in the systematics

Predictions of different generators: PYTHIA and HERWIG++



Systematics:

JES: 4-6% for p_T>75 GeV, varying jet p_T (CMS PAS JME-09-004 (2009))

✓*Angular resolution*: much smaller than other uncertainties

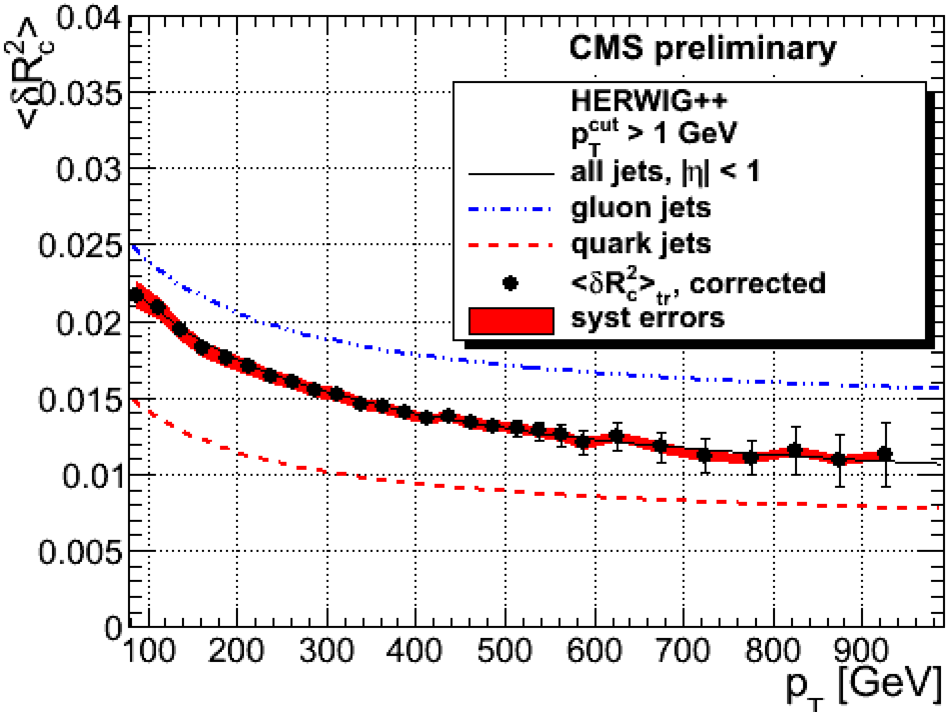
✓*Tracker pT resolution*: varying track p_T cut by 1% (CMS PAS TRK-09-001 (2009))

✓*Simulation bias correction*: half of the difference between HERWIG++ and PYTHIA bias corrections

Stat.errors: corresponds to 10 pb^{-1} (but data points were produced using samples with more statistics)

The data sample for 10 pb^{-1} will allow to distinguish between predictions of different MC generators

Estimation of quark jet fraction



Stat.errors: corresponds to 10 pb^{-1} (but data points were produced using samples with more statistics)

After achieving agreement between MC tuned predictions for $<\delta R^2_c>$ vs p_T^{jet} it can be compared with the result of simulations for quark and gluon jets

Conclusions

✓Jet transverse structure is sensitive to the event generator and can also be used as a quantitative analysis of the fraction of quark and gluon jets

✓Using transverse structure measurements based on the tracker instead of the calorimeter reduces measurement bias

✓10 pb^{-1} of data collected with the CMS experiment is sufficient to distinguish between different Monte Carlo generators

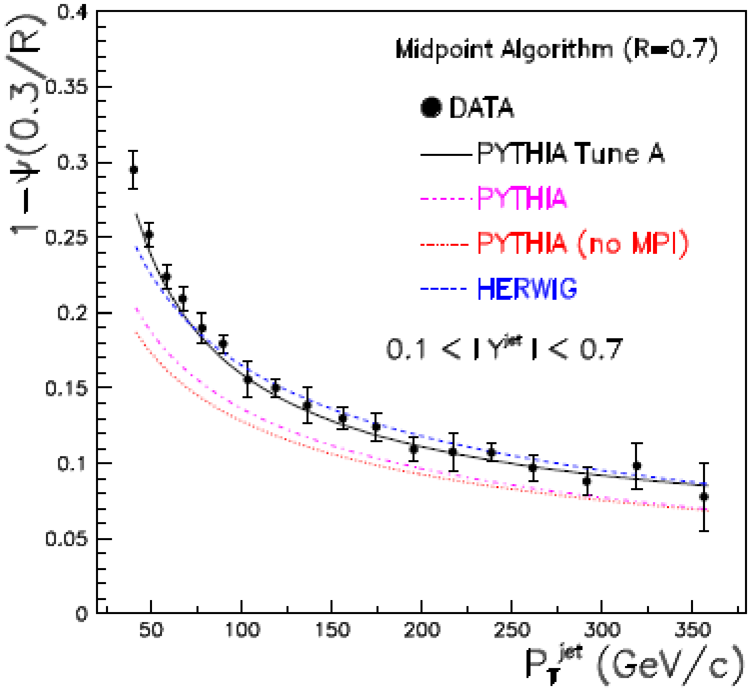
✓Pythia and Herwig++ predict no dependence of δR^2 on η for both gluon and quark jets. The η dependence of δR^2 for all jets is due to the difference in the quark and gluon fraction as a function of η

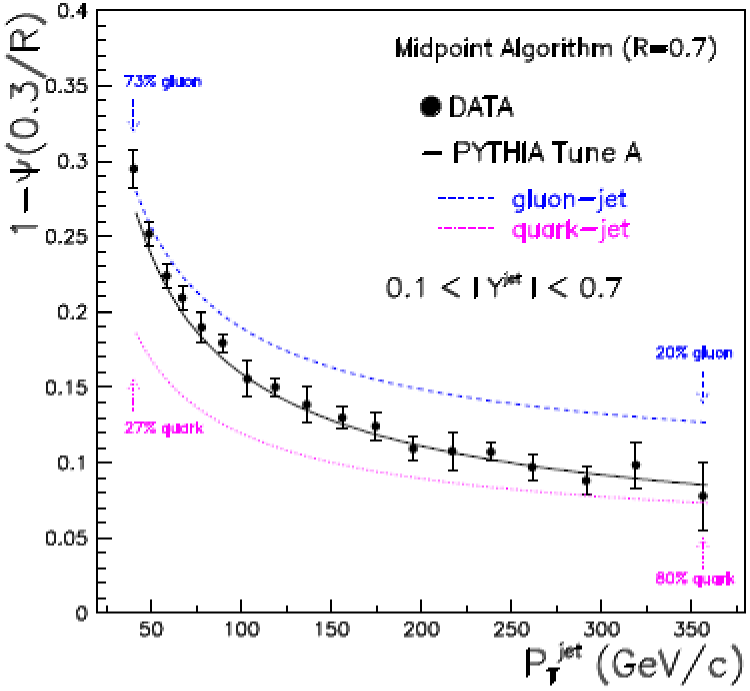
✓After tuning the Monte Carlo to data, the quark jet fraction can be extracted

Back-up

Tevatron results

CDF results: Phys.Rev. D71, 112002 (2005);





MC samples

- ✓ Summer08 MC samples:
  PYTHIA6.4 tune D6T and HERWIG++2.2
- ✓ 10 pb^{-1}
- ✓ CMSSW221 for analysis
- ✓ standard CMS single jet triggers
  (1E31 trigger menu)
- ✓ IC algo (R=0.5) for jets reconstruction
- ✓ JEC - L2L3 calo corrections
  (CMS PAS JME-07-002 (2007))
  and
  JPT - JetPlusTrack algo for jet energy
  (CMS PAS JME-09-002 (2009))