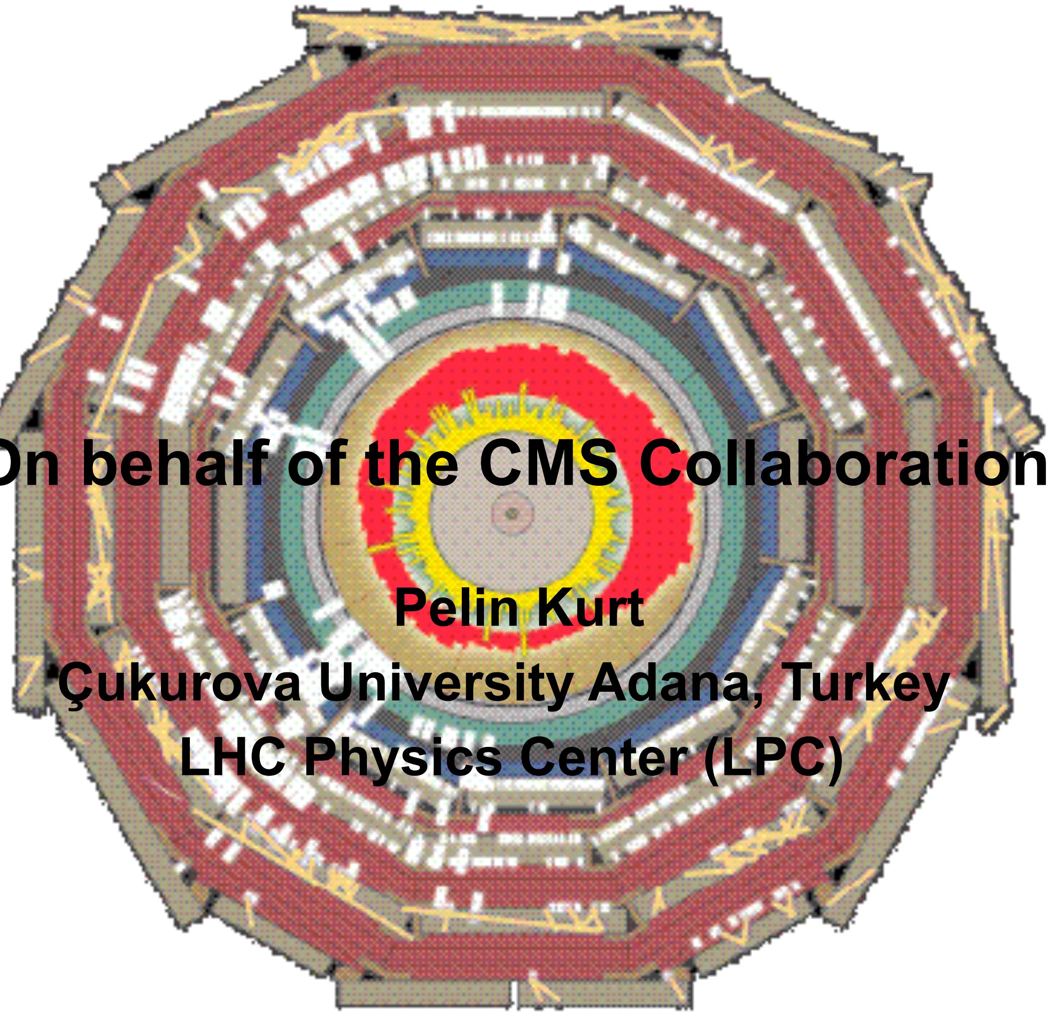
Jet Shapes at CMS



"On behalf of the CMS Collaboration"

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LHC Physics Center (LPC)

International Conference on Particle Physics

In Memoriam Engin Arık and Her Colleagues

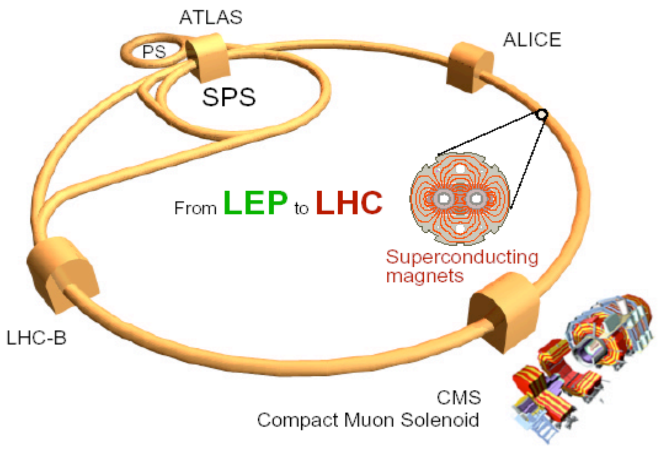
Boğaziçi University, istanbul, Turkey, October 27-31, 2008

Outline

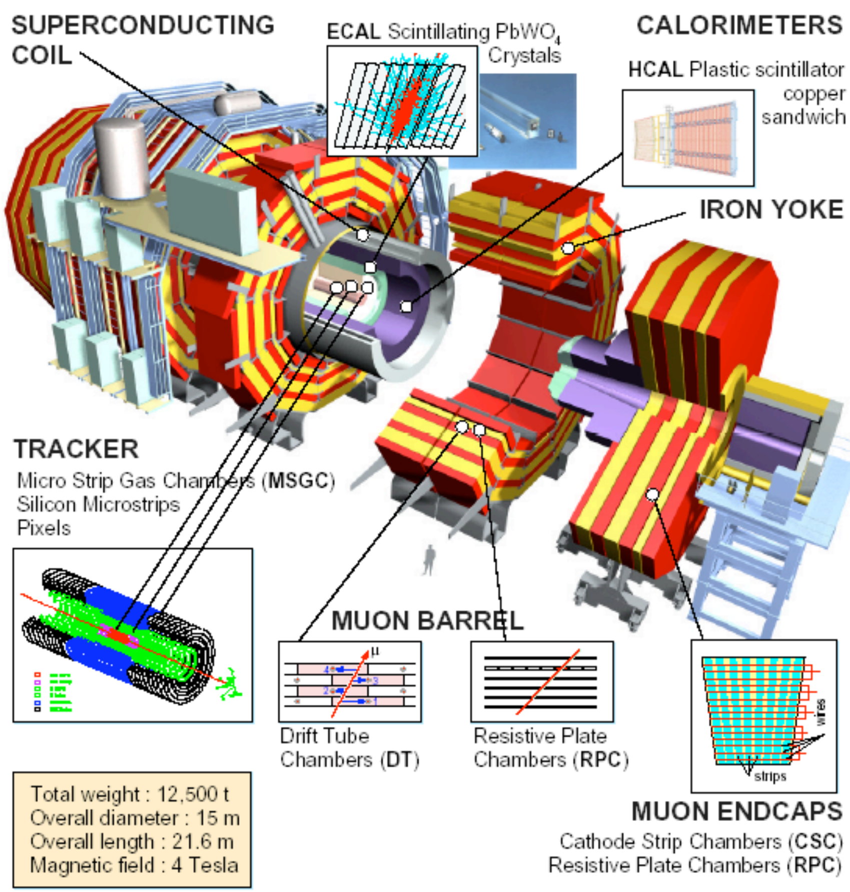
- Motivation
- Jet Reconstruction
- Jet Shapes
- Sensitivities
- Quark and Gluon Jet Fraction
- Summary

The Large Hadron Collider and CMS

LHC will collide beams of protons up to 14TeV.



	Beams	Energy		Luminosity
LEP	e+ e-	200	GeV	10^{32} cm^{-2}s^{-1}
LHC	p p	14	TeV	10^{34}
	Pb Pb	1312	TeV	10^{27}



Motivation

Jets are one of the experimental signatures of quarks and gluons from hard collisions.
Jet Shapes measure the energy flow distribution within a jet.

- Test showering models in Monte Carlo generators
- Discriminate between different underlying event models
- Provide insight into performance of jet clustering algorithms
- Possible application in searches for new physics
- Previous measurements have been done in $p\bar{p}$, *ep* and *ee* colliders
- **References:**

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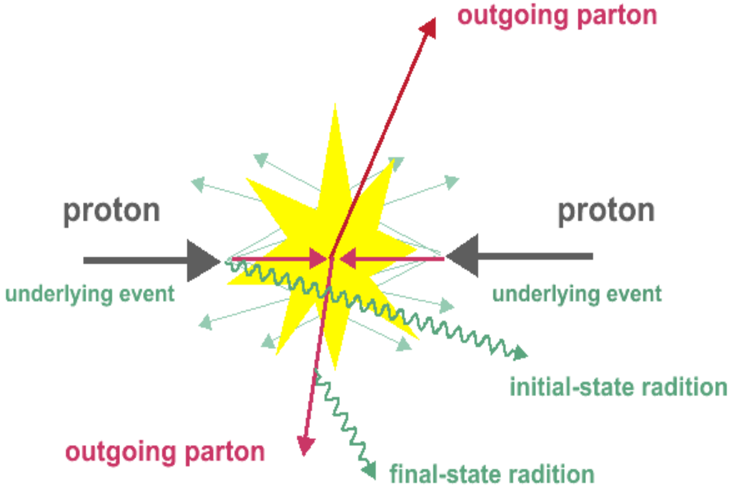


Jet Algorithms

Jet finding algorithms are used to associate particles to particular jet.

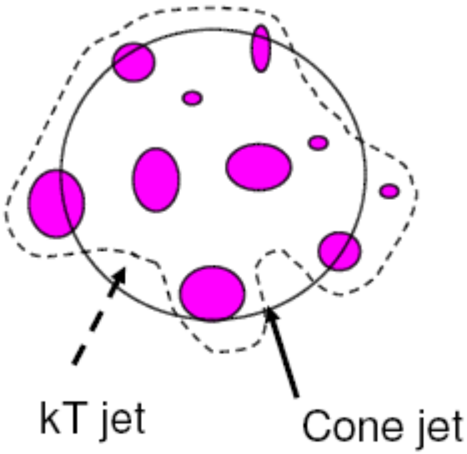
Major classes of jet algorithms:

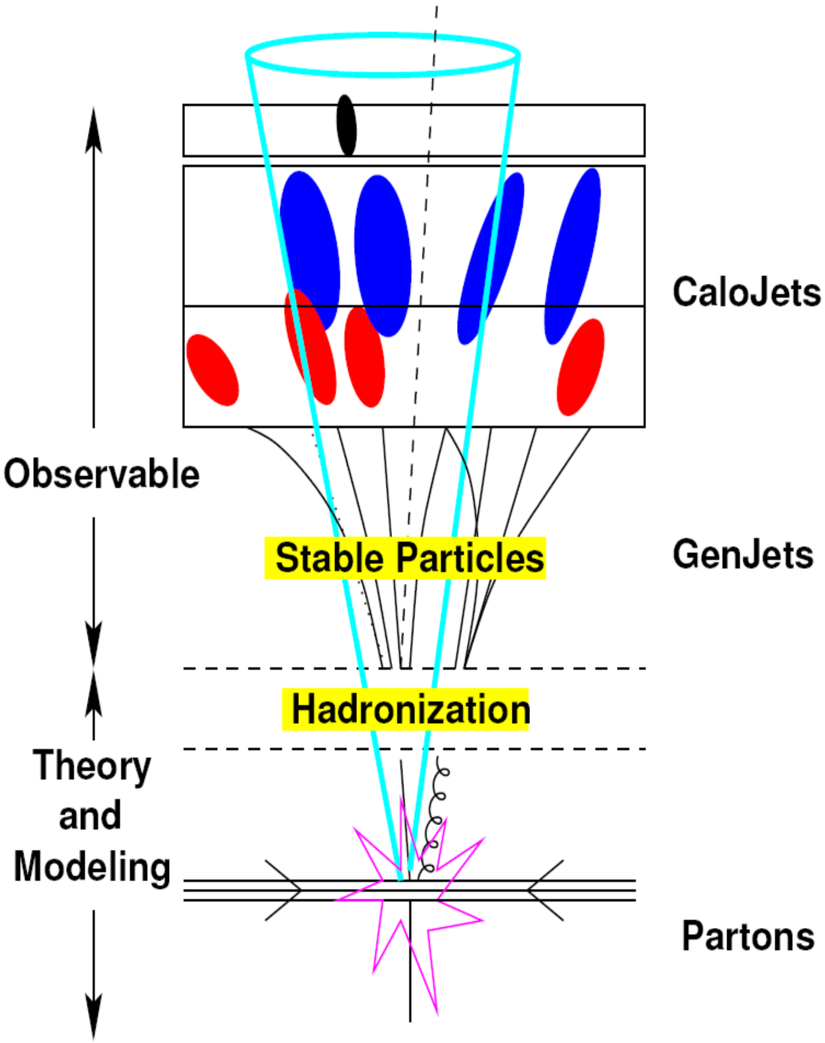
Cone: cluster objects close in angle

Simple shape, unless jets overlap

kT: cluster objects close in relative P_T

Irregular shape





Jet Algorithms in CMS

SISCone

- Seedless IRC Safe Cone algorithm
- Searches for all stable cones of size $R=\sqrt{((\Delta y)^2 + (\Delta \Phi)^2)}$
- Applies splitting/merging
- No remaining unclustered inputs

(Fast) kT

- Controlled by the jet separation parameter D (determines jet "size")
- Uses sequential recombination of 4vectors
- based on relative kT
- Infrared Collinear safe

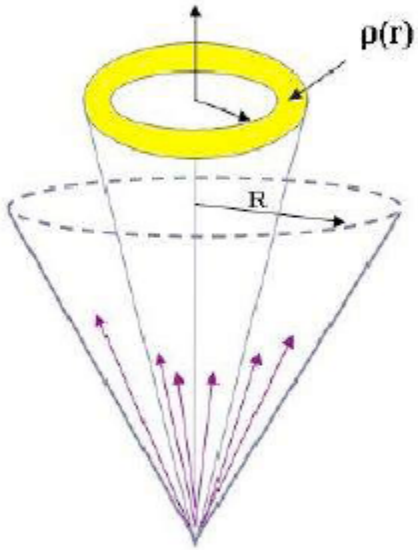
Iterative Cone (ICone)

- Iteratively searches for stable cones
- input objects assigned to a jet are removed before the next iteration
- No splitting/merging
- Seed based, not IRC safe
- Seed E_T > 1 GeV

Midpoint Cone (MCone)

- Also seed based
- Adds extra seeds between stable cones ("midpoints")
- Not Infrared Collinear safe
- Does not remove "used" inputs
- Applies splitting/merging
- Leaves unclustered energy

Jet Shapes



$$R=\sqrt{\Delta y^2+\Delta\varphi^2}$$

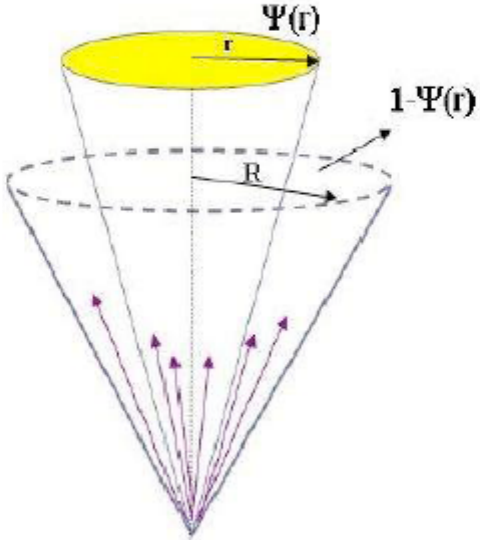
Differential Jet Shape

$$\rho(r)=\frac{1}{\delta r}\frac{1}{N_{jets}}\sum_{jets}\frac{p_T(r-\delta r/2, r+\delta r/2)}{P_T(0,R)}$$

Definition: The average fraction of the jet's transverse momentum that lies inside an annulus in the y-Φ plane of inner (outer) radius r-Δr/2 (r+Δr/2) concentric to the jet cone.

Definition : Integrated jet shape is defined as the average fraction of jet transverse momentum that lies inside a cone of radius r concentric to the jet axis.

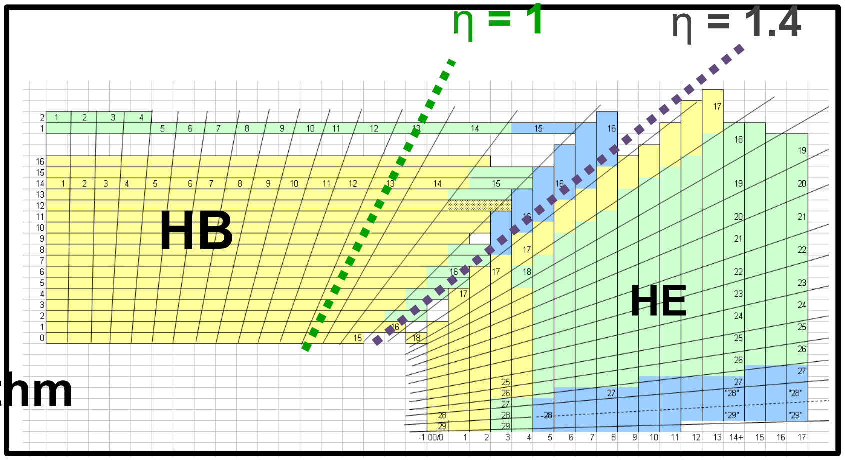
$$\Psi(r)=\frac{1}{N_{jets}}\sum_{jets}\frac{P_T(0,r)}{P_T^{jet}(0,R)}$$



Integrated Jet Shape

Data sets and Definitions

HCAL towers and η cut



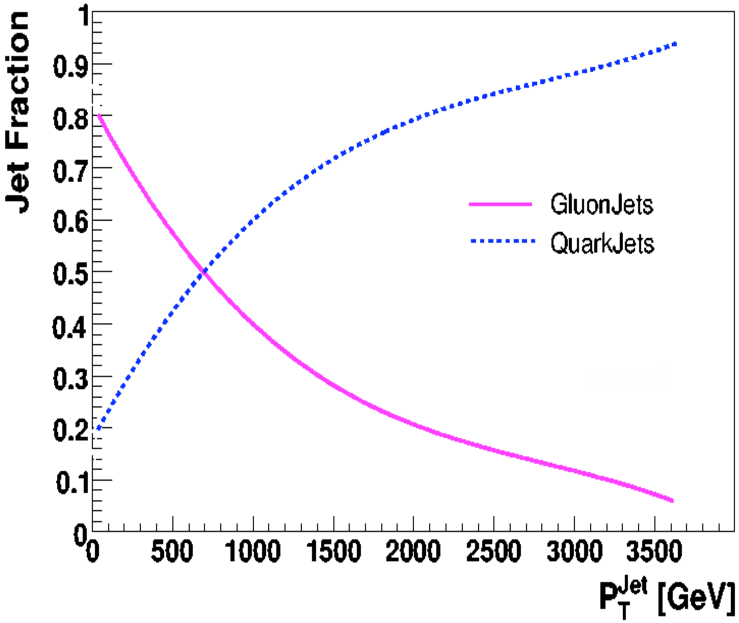
- QCD dijet samples (PYTHIA, HERWIG++)
- Calorimeter Towers E_T>0.5 GeV

Clustering Algorithm Study :

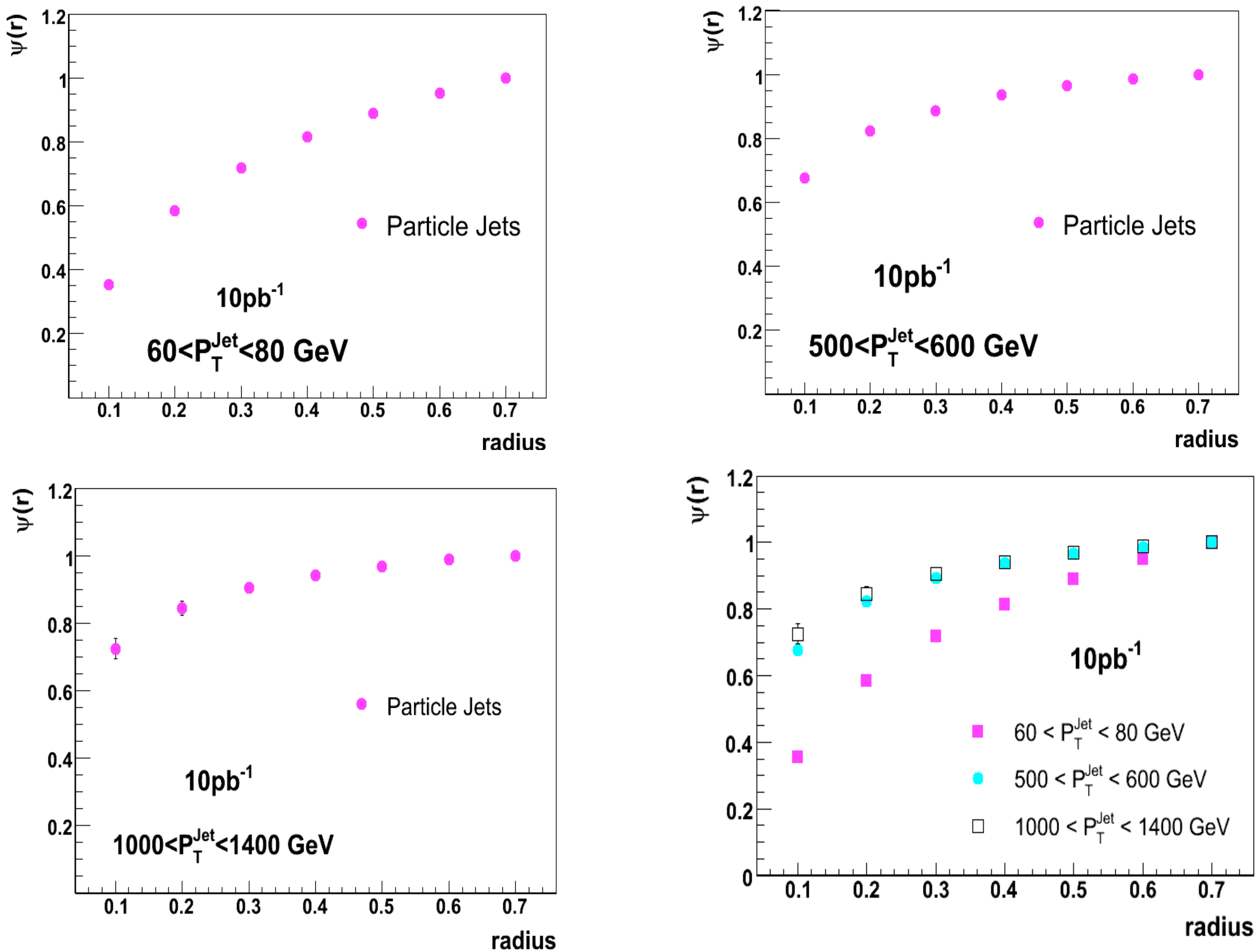
- Only particles/towers associated to jet by algorithm
- Midpoint Cone (MCone) , Iterative Cone (ICone),
- Seedless Infrared Safe Cone (SISCone)
- (cone radius R=0.5)
- kT (size parameter D=0.4, D=0.6 and D=1.0)

Jet Shape Study :

- Jet axis from SISCone R=0.7
- All particles/towers within R=0.7 of jet axis

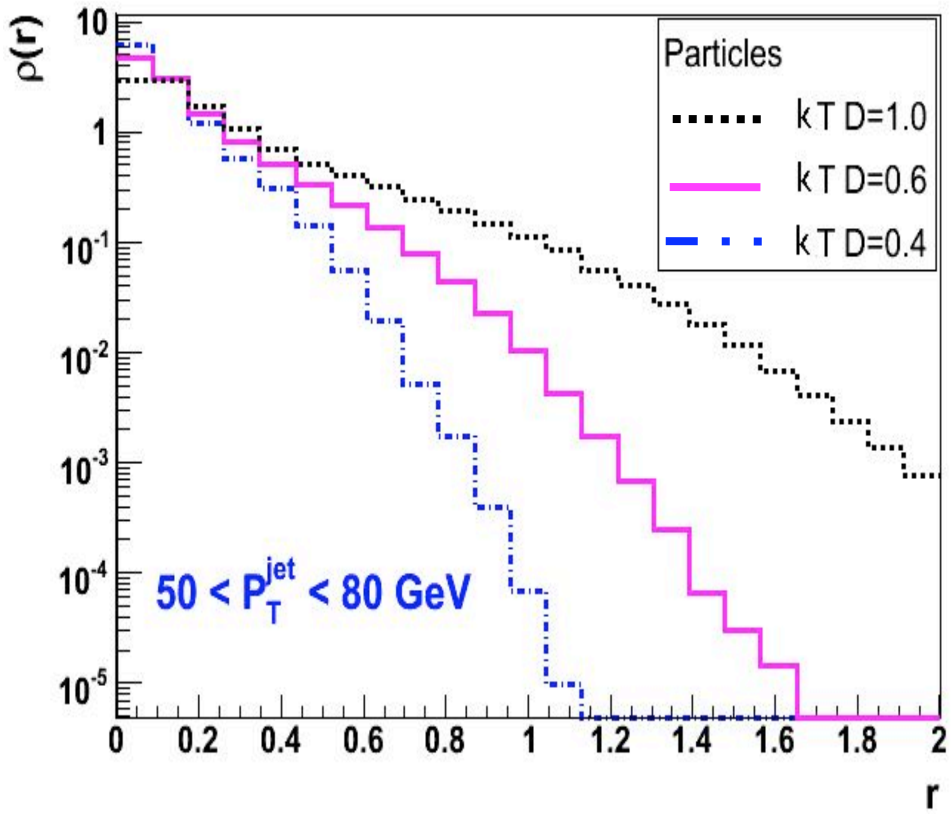


Integrated Jet Shapes



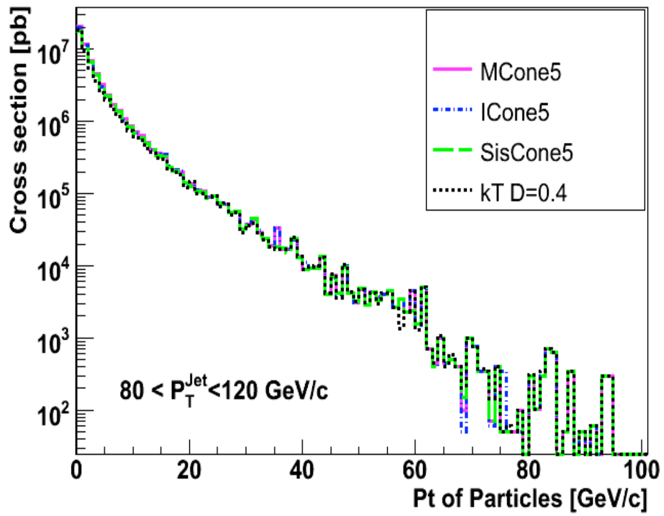
The jet shapes get narrower with increasing jet P_T.

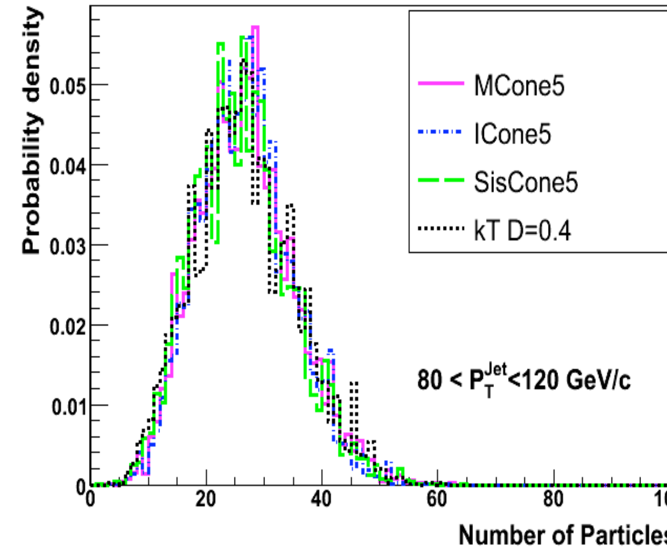
Clustering Study of kT Algorithm

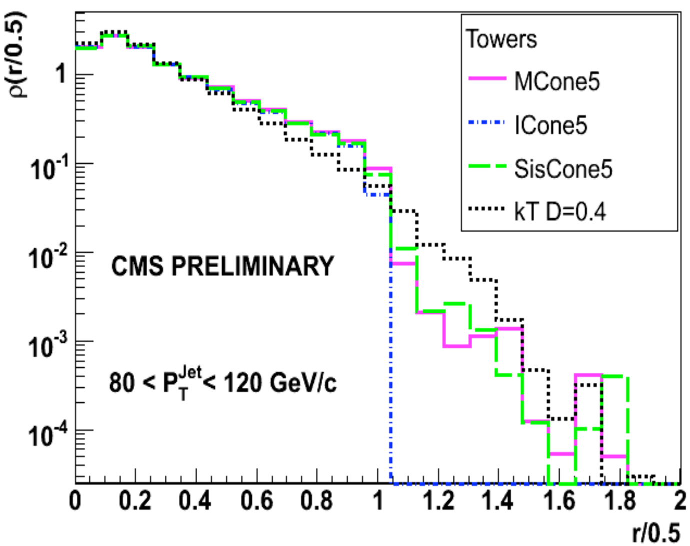


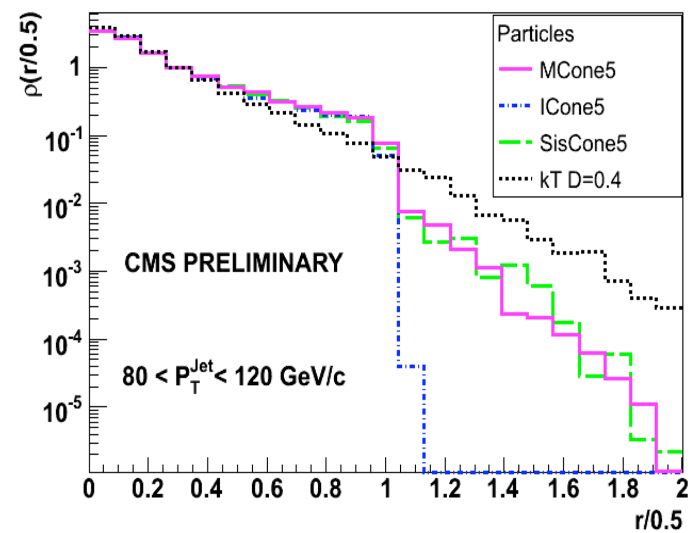
The performance of the kT jet clustering algorithm was tested by looking into the internal structure of jets by PYTHIA DWT. Jets with larger D extends to larger distances.

Study of Jet Algorithms





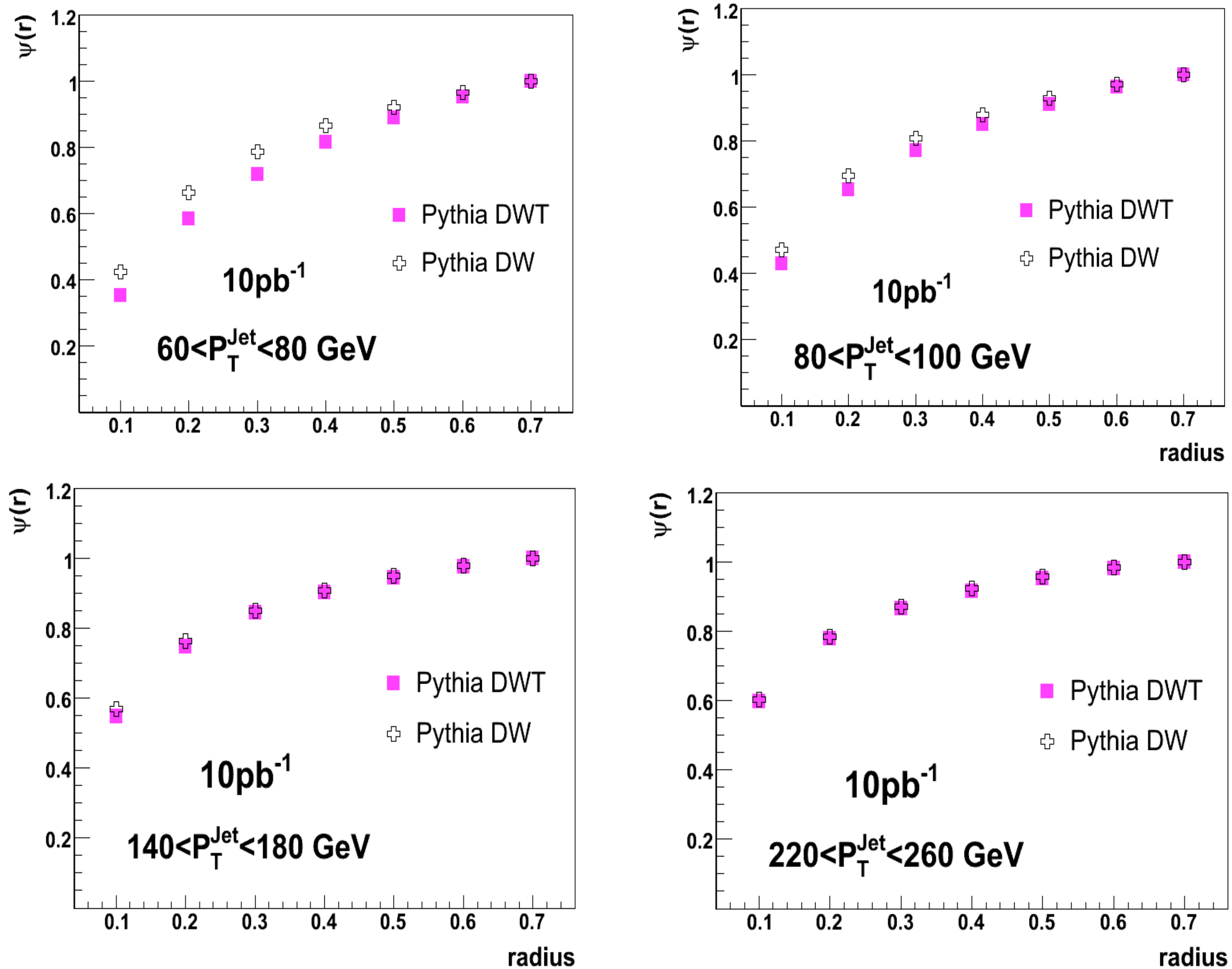




kT jet properties are similar to the properties of jets clustered by the cone algorithms (CMS-PAS-JME-07-003). Shown results are from particle and calorimeter level as given by PYTHIA DWT.

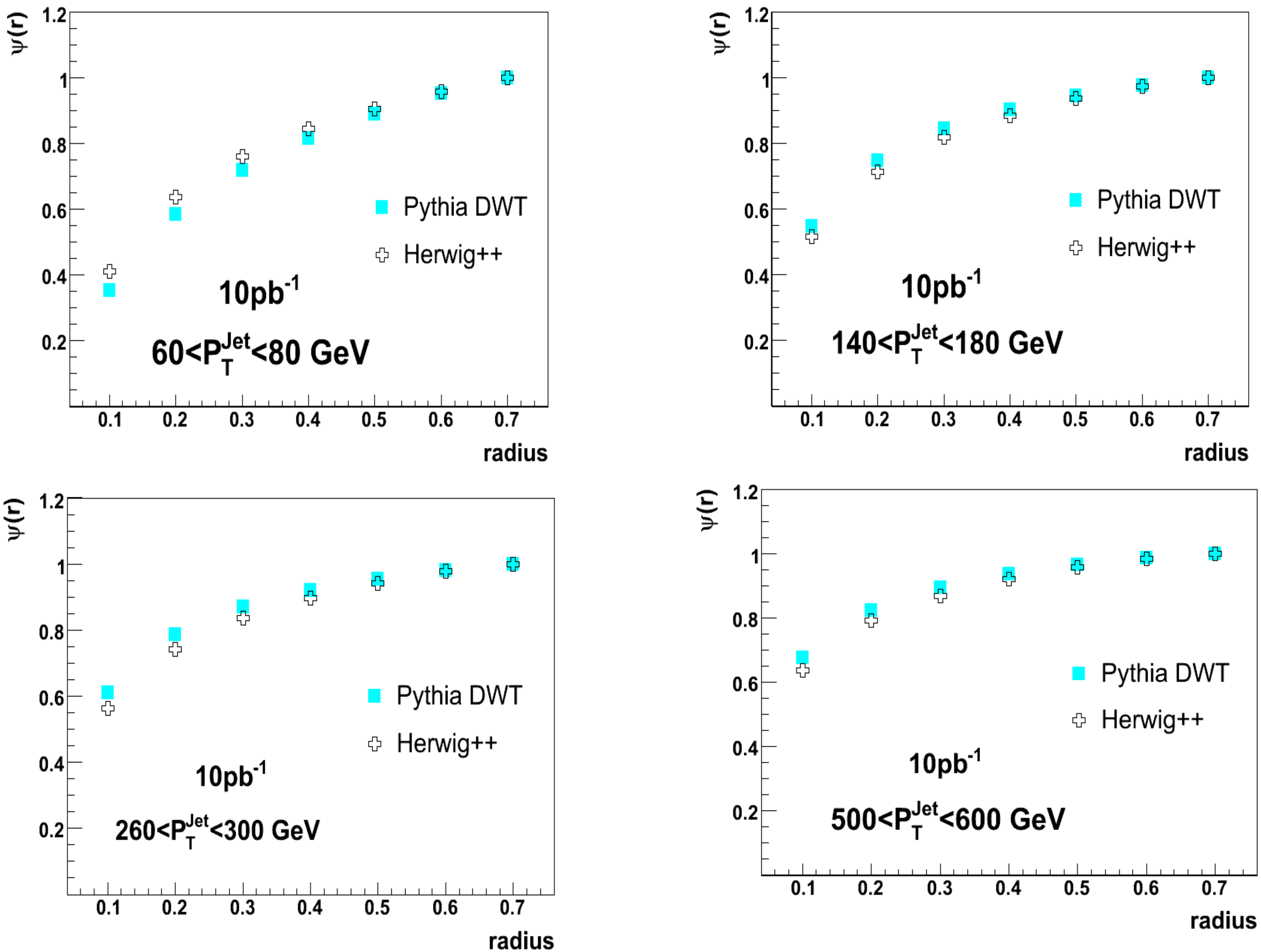
Pythia events with different Underlying Event Tune

Well tuned MC's are essential for a precise measurement and proper comparison with the theoretical predictions.



- Pythia Tune DWT predicts a more active UE at the LHC (see CMS Note 2006/067)
- Different √s extrapolations from the same tune at CDF/ Tevatron energy.

Monte Carlo Event Generators

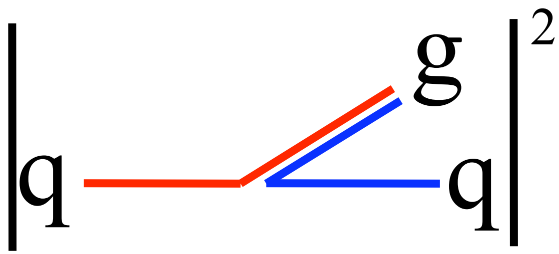


Two different Monte Carlo Tune PYTHIA DWT and HERWIG++ were compared.

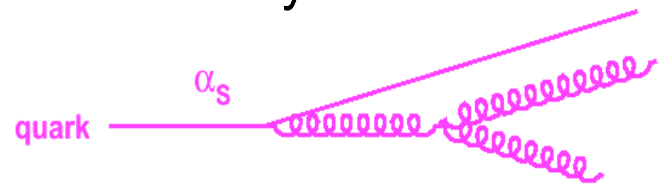
Quark & Gluon Jets

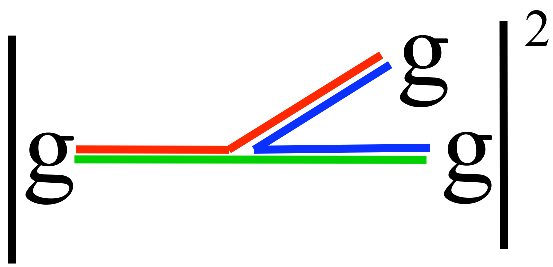
Quark & Gluon jets radiate proportionally to their color factor

- Jet profiles are sensitive to the quark/gluon jet mixture
- Could separate quark and gluon jets in a statistical way

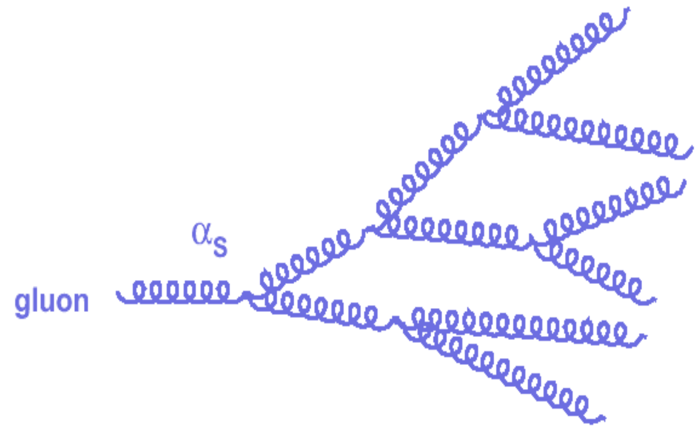


$\sim C_F = 4/3$





$\sim C_A = 3$



C_F ~ strength of a gluon coupling to a quark

C_A ~ strength of the gluon self coupling

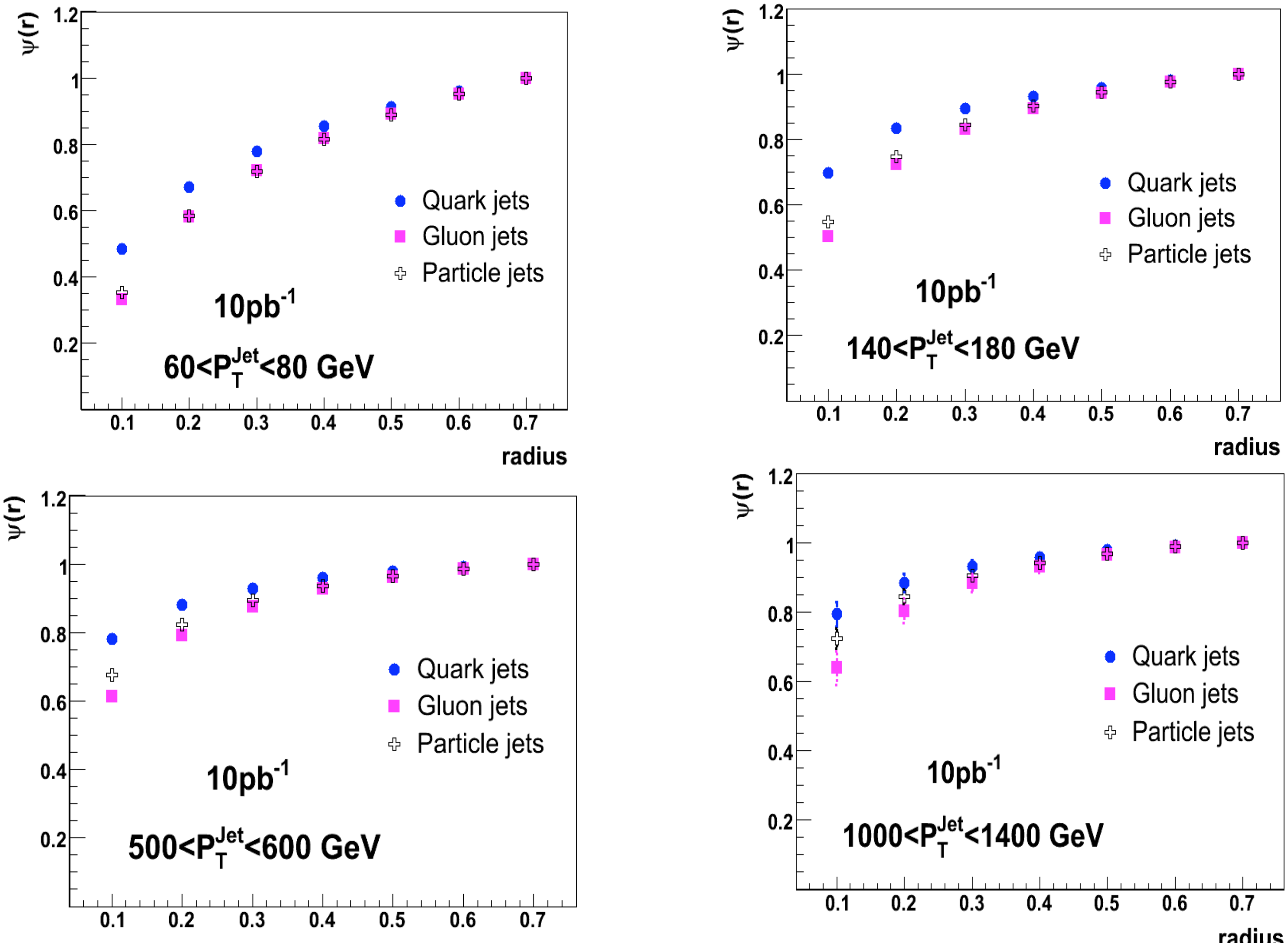
At Leading Order ($E_{jet} \to \infty$):

$$r \sim \frac{C_A}{C_F} = \frac{9}{4} = 2.25$$

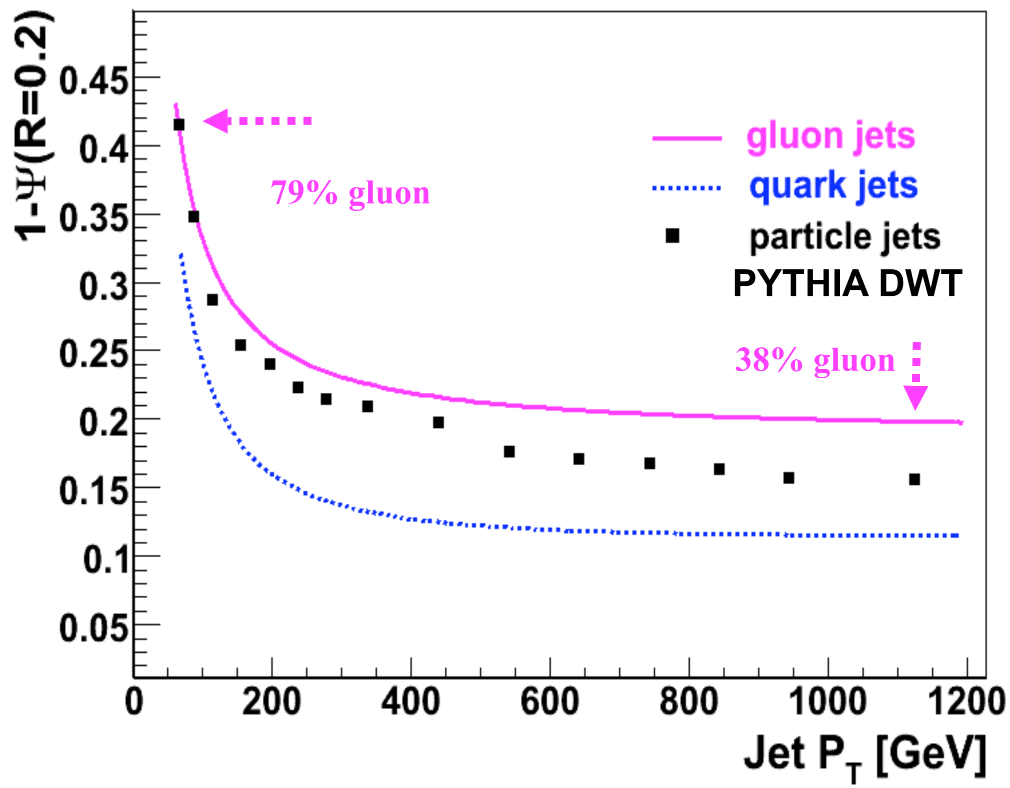
Color factors reflect basic properties of QCD. Quark jets are narrower than the gluon jets due to the coupling strengths. Therefore the jets produced by quarks and gluons will show differences in their average particle multiplicity and the shape of the spectrum constituents.

Quark and Gluon Jet Contributions

- Monte Carlo predicts that the measured jet shapes are dominated by contributions from gluon initiated jets at low jet P_T while contributions from quark initiated jets become important at high jet P_T .



Quark and Gluon Fraction



- Mixture of the quark and gluons in the final state changes with jet P_T contribution to the jet shape dependence on P_T .
- PYTHIA predicts the fraction of the gluon initiated jets as 79% at low jet P_T and about 38% at high P_T
- Jets become more collimated with the increasing jet P_T since α_s **(P_T)** decreases with the increasing jet P_T
- Quark jets are narrower than the gluon jets since quarks have smaller **color charge**.

Summary

- Using PYTHIA and HERWIG++ MC simulations we have estimated a technique to measure jet shapes in p-p collisions at 14 TeV.
- Jets get narrower with the increasing jet P_T.
- Different UE tunes have been investigated. PYTHIA DW tends to produce narrower jets at the low P_T.
- Quark jets are narrower than the gluon jets.
- A full study including CMS simulation is in preparation.