Jet properties in proton-proton collisions at the LHC energy

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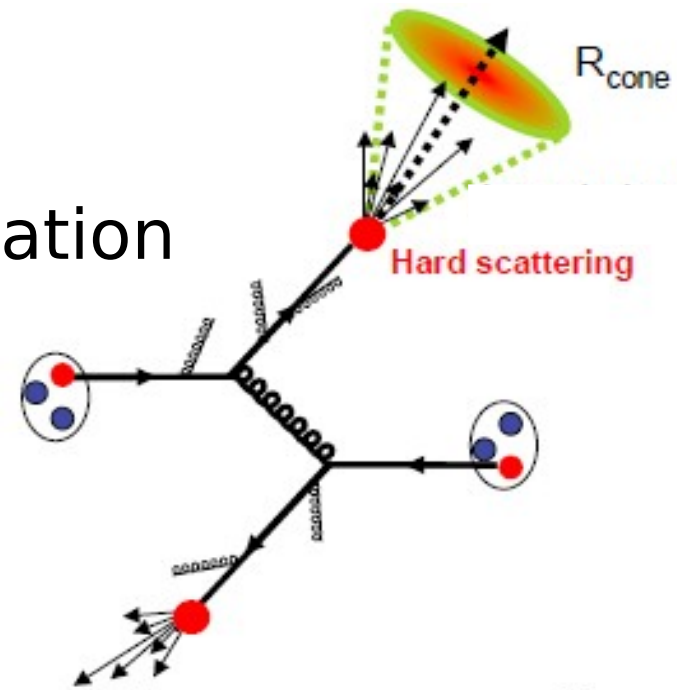
Outline

- **Motivation :**
  - ➔ Introduction to jets
  - ➔ Significance of jet study
- **List of observables studied**
- **Analysis and Results**
- **Summary**

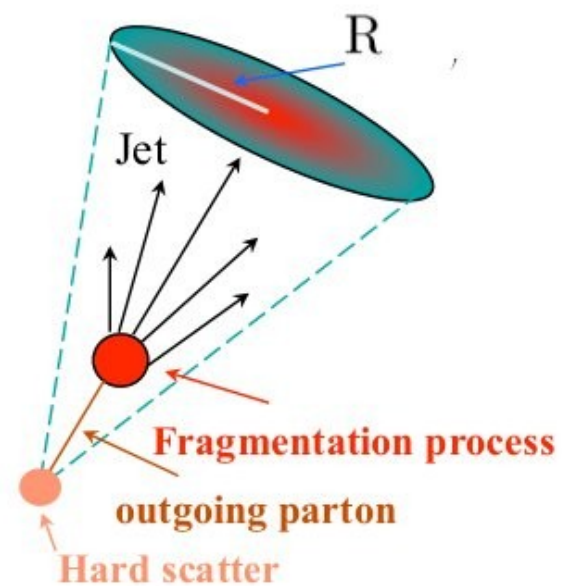
Jet production

Jet: Collimated spray of hadrons produced from the fragmentation of hard parton



The physics of hadronic jets
Luigi DiLella : doi:10.1016/j.physrep.2004.08.012

Experimentally, jets are reconstructed from the measured hadrons with the help of jet finding algorithms



Why jets?

Jets are the experimental tool to understand parton kinematics:

- pQCD : partonic level
- Experiments measure hadrons
- Re-associate measurable hadrons to accurately reconstruct parton kinematics
- Tools : **Jet finding algorithms**. Same algorithm for experimental and theoretical calculations

Jets provide :

- Proxy to the high p_T partons produced in the collision
- An important tool to test pQCD
- Details of parton to jet fragmentation
- A smoking gun signature to probe the hot and dense medium produced in AA collisions via the energy loss mechanism known as **jet quenching**

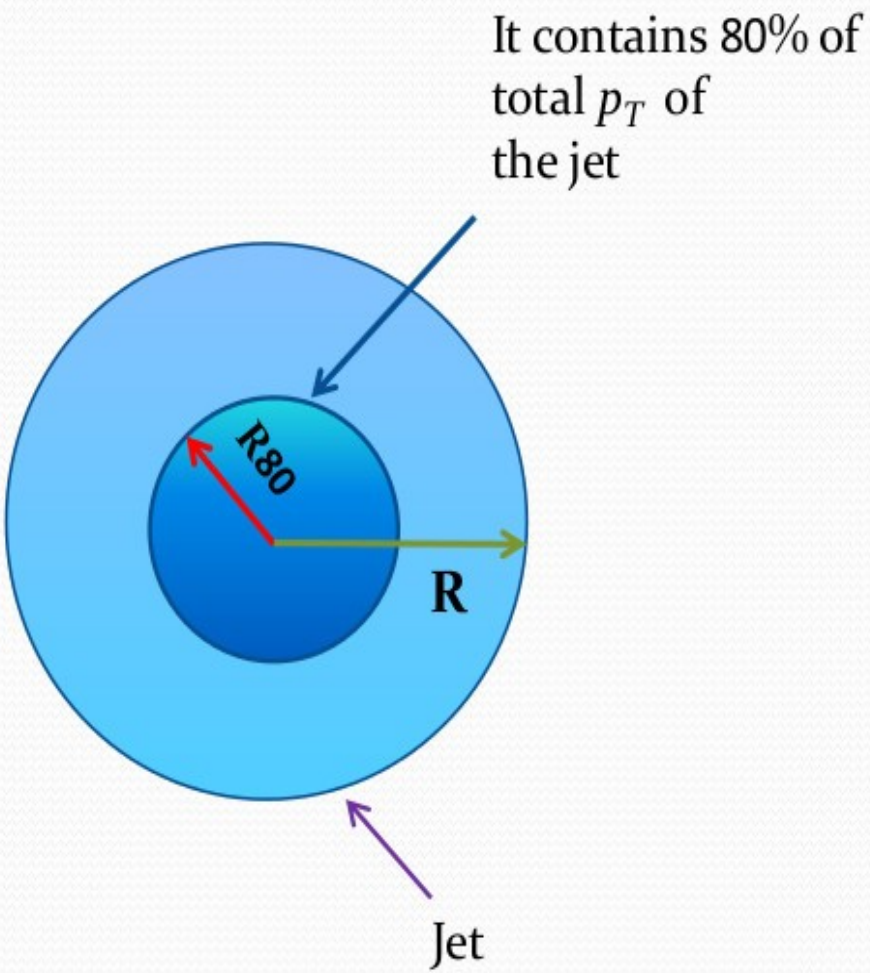
Jet Observables

- Mean Particle Multiplicity, <***N***> is defined as the average no. of particles found within a jet.

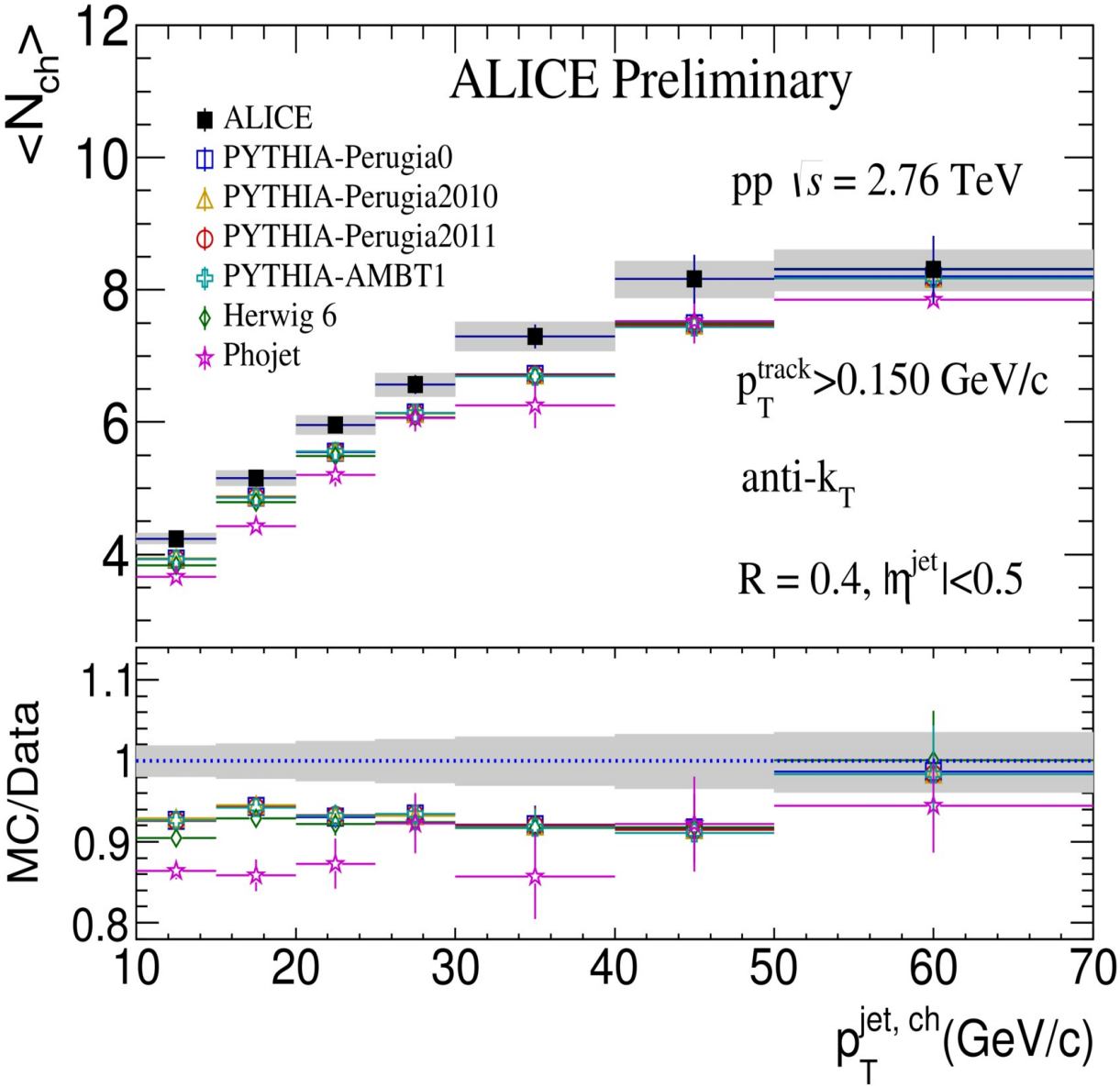
$$\langle N \rangle = \frac{1}{N_{jets}} \sum_{i=1}^{N_{jets}} N_i$$

where N_i denotes the no. of particles in the ith jet.

- The size of the jet, ***R80***, is defined as the radius in the η-ϕ space that contains 80% of the total p_T found in the jet.



Charged particle multiplicity distribution in leading jet



- Charged jet measurement, R = 0.4
- $\langle N_{ch} \rangle$ increases with increasing jet p_T

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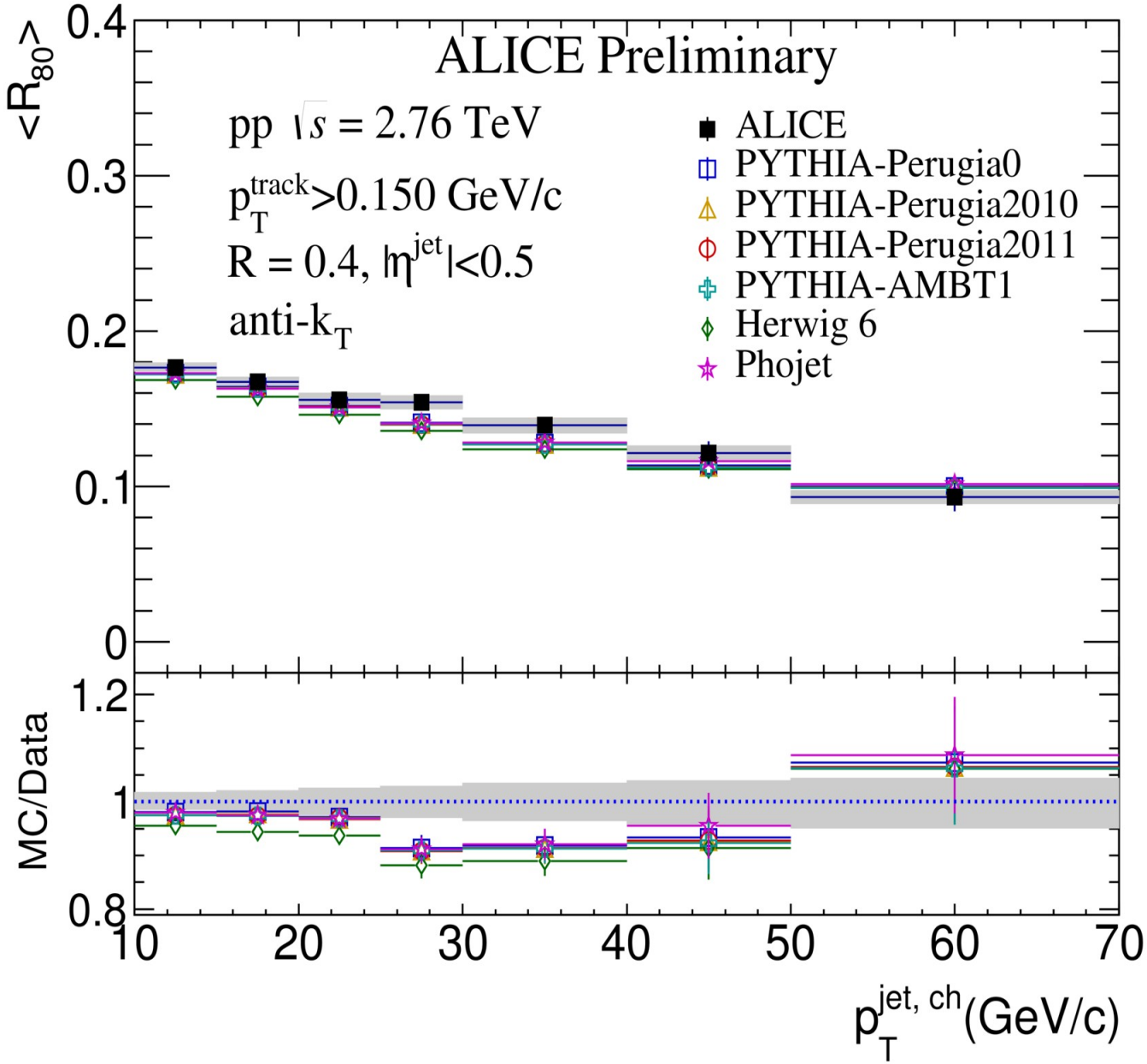
Jet size (R_{80})



- For lowest jet p_T bin, 80% of the jet p_T is contained within half of the jet radius
- For higher jet p_T bin, $\langle R_{80} \rangle$ decreases down to even smaller cone

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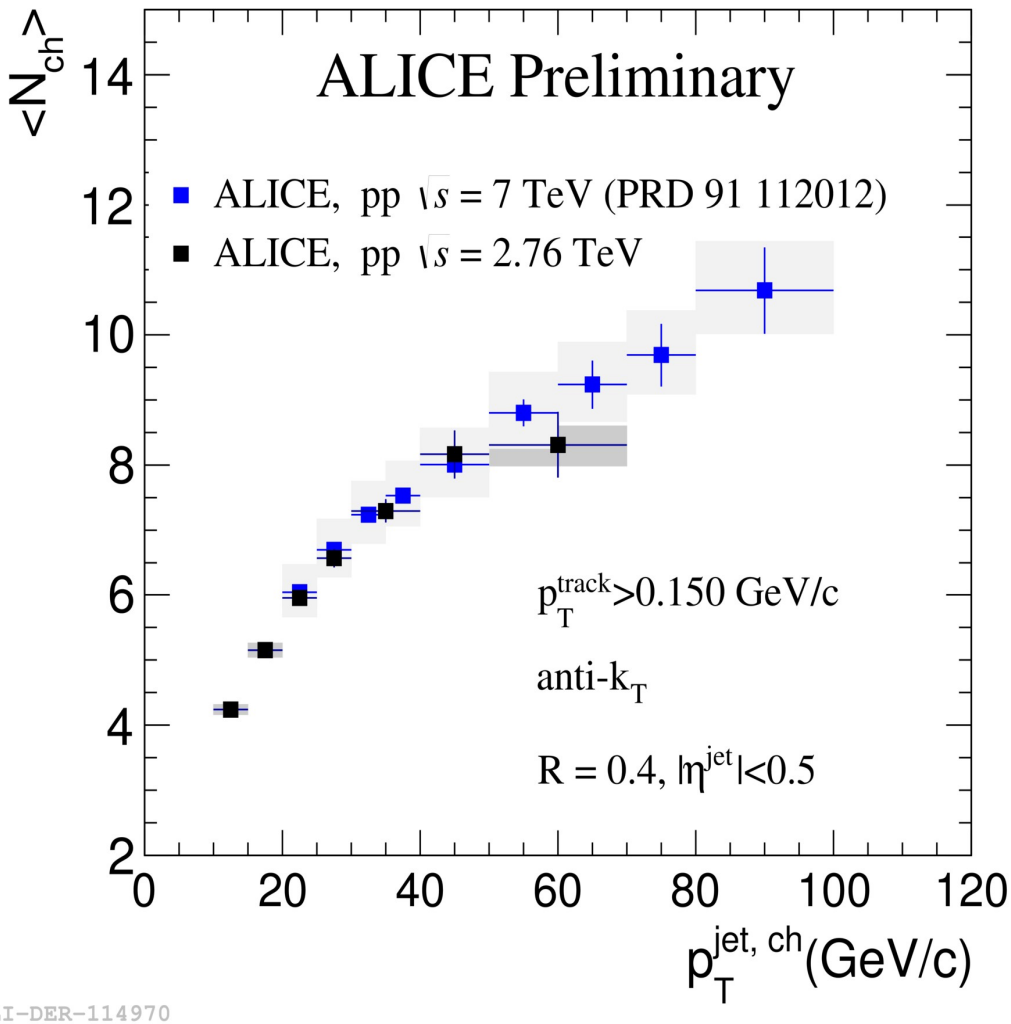
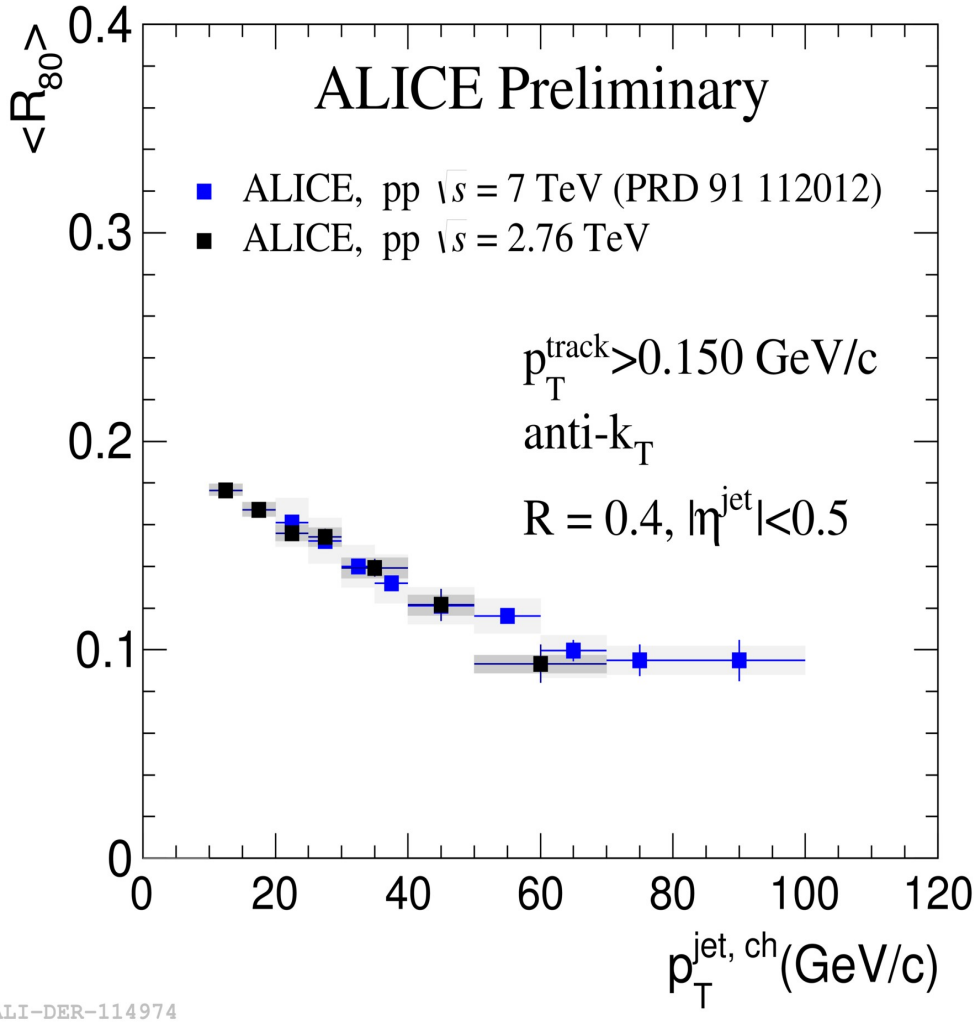
Comparison between two √s





Within uncertainties, no such √s dependence

Analysis details

- Data Generation
  1. PYTHIA simulation
  2. $\sqrt{s} = 2.76$, 7, 13 TeV
- Particle Selection
  1. $p_T > 0.15$ GeV/c
  2. $|\eta| < 0.9$
- Jet Selection
  1. $15 < p_T^{jet} < 150$ GeV/c.
  2. $|\eta| < 0.5$
  3. Jet resolution parameter R = 0.4

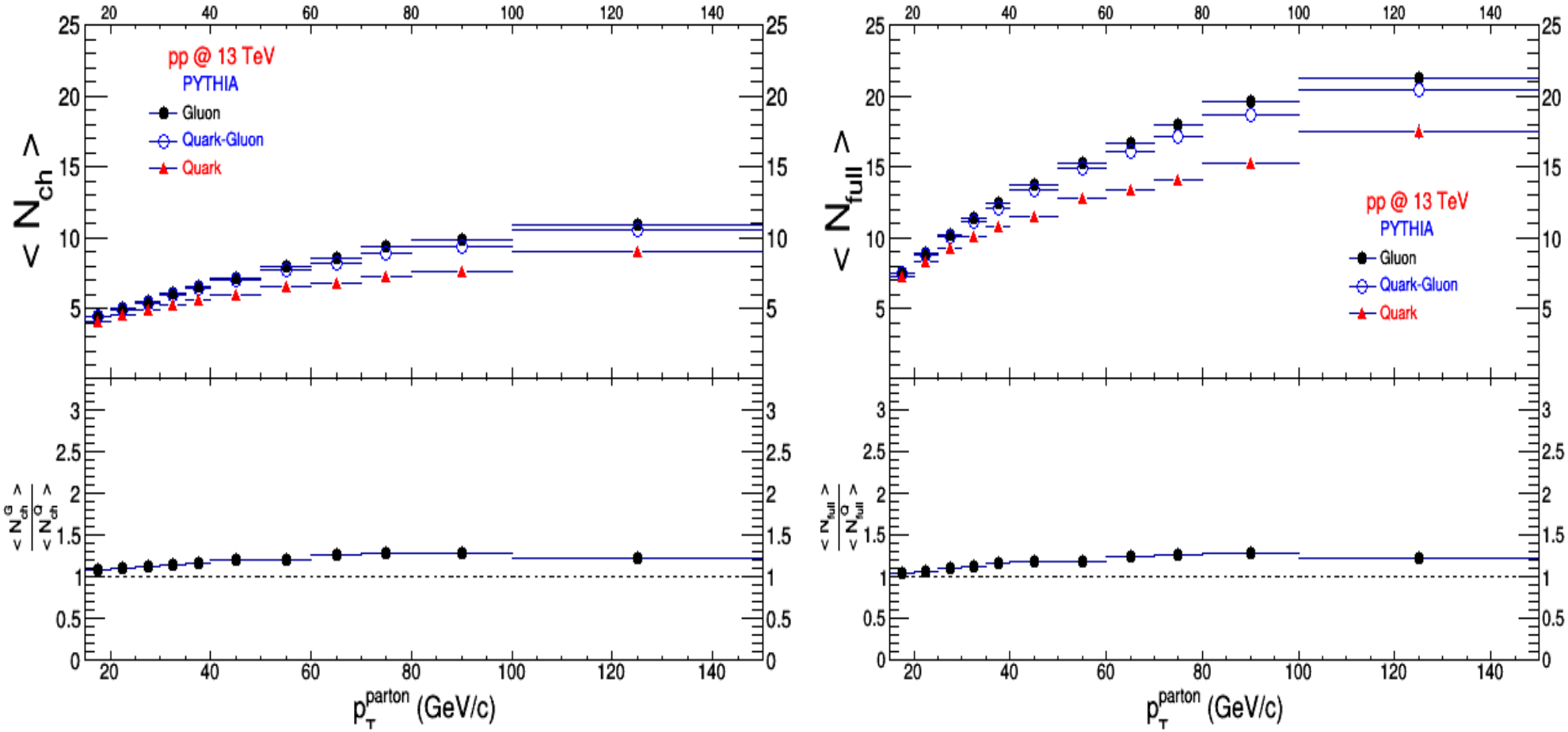
- Quark Jet : Reconstructed jet produced by hard scattered quark.
- Gluon Jet : Reconstructed jet produced by hard scattered gluon.
- Full jet : Jet reconstructed using the information of all particles.
- Charged jet : Jet reconstructed using the information of only charge particles.

Jet matching algorithm

- It is developed to match the jets with the hard scattered partons from which they are produced
- one to one correspondence
- Closest Distance Approach (CDA)
- Conditions to avoid fake matching

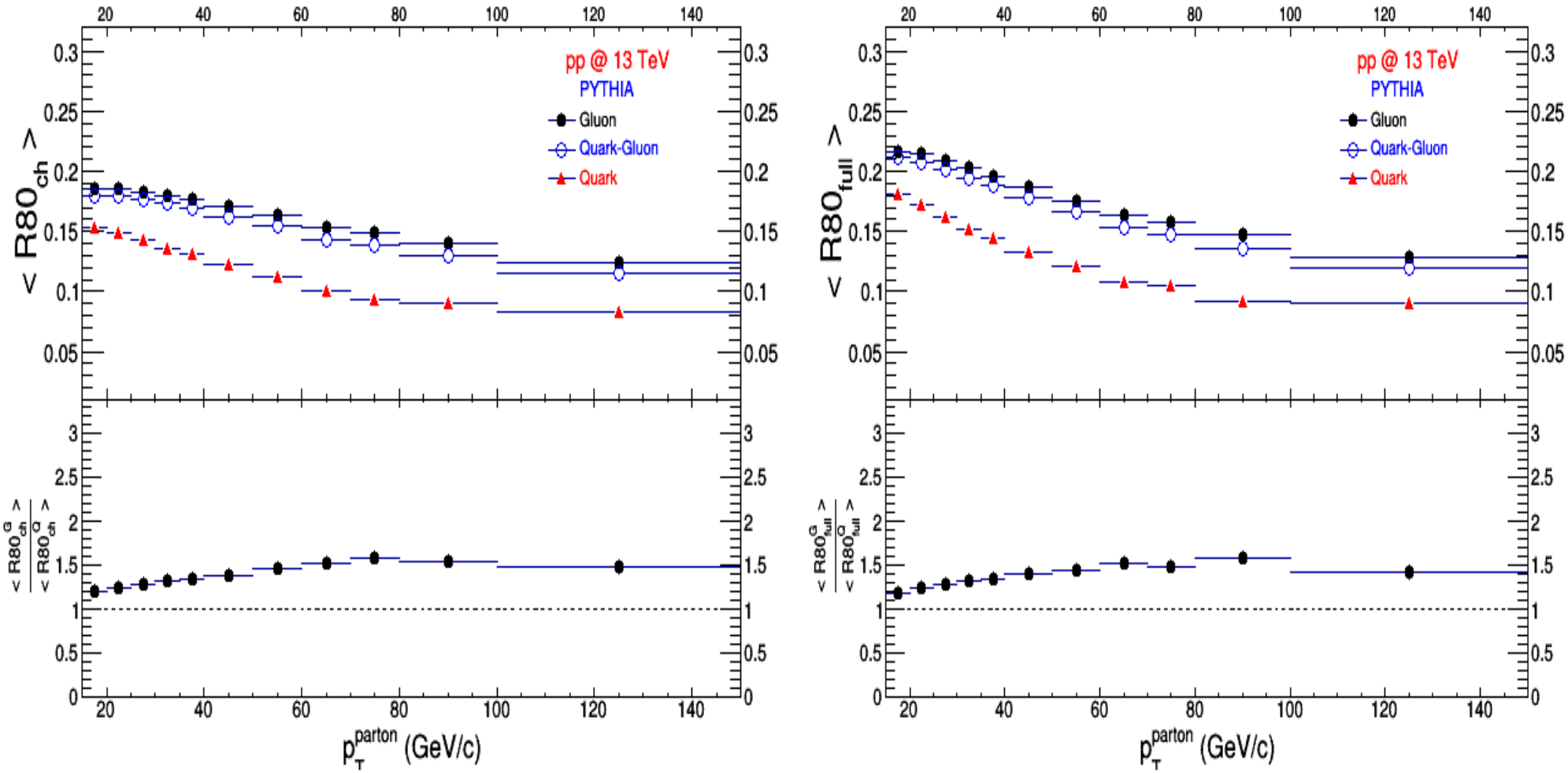
1. $p_{T,Jet}$ is greater than 20% of p_T of matched parton.
2. $\Delta\phi$ between the matched pair of parton and jet must be less than $\pi/2$.

Mean multiplicity distributions in charged and full jet



- $\langle N \rangle$ rises monotonically with increasing parton p_T.
- $\langle N \rangle$ coming from gluon is greater than that coming from quark for both charged and full jets.

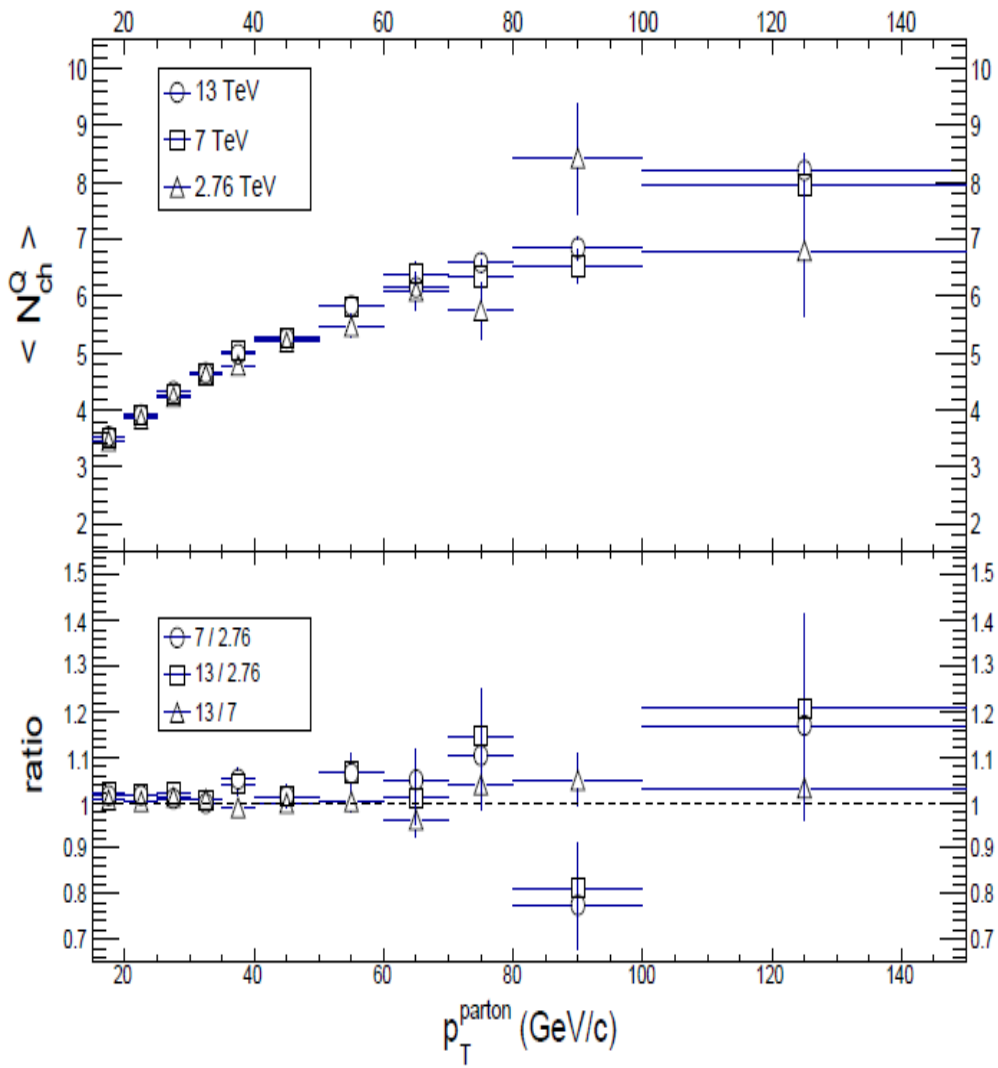
R_{80} distributions in charged and full jet



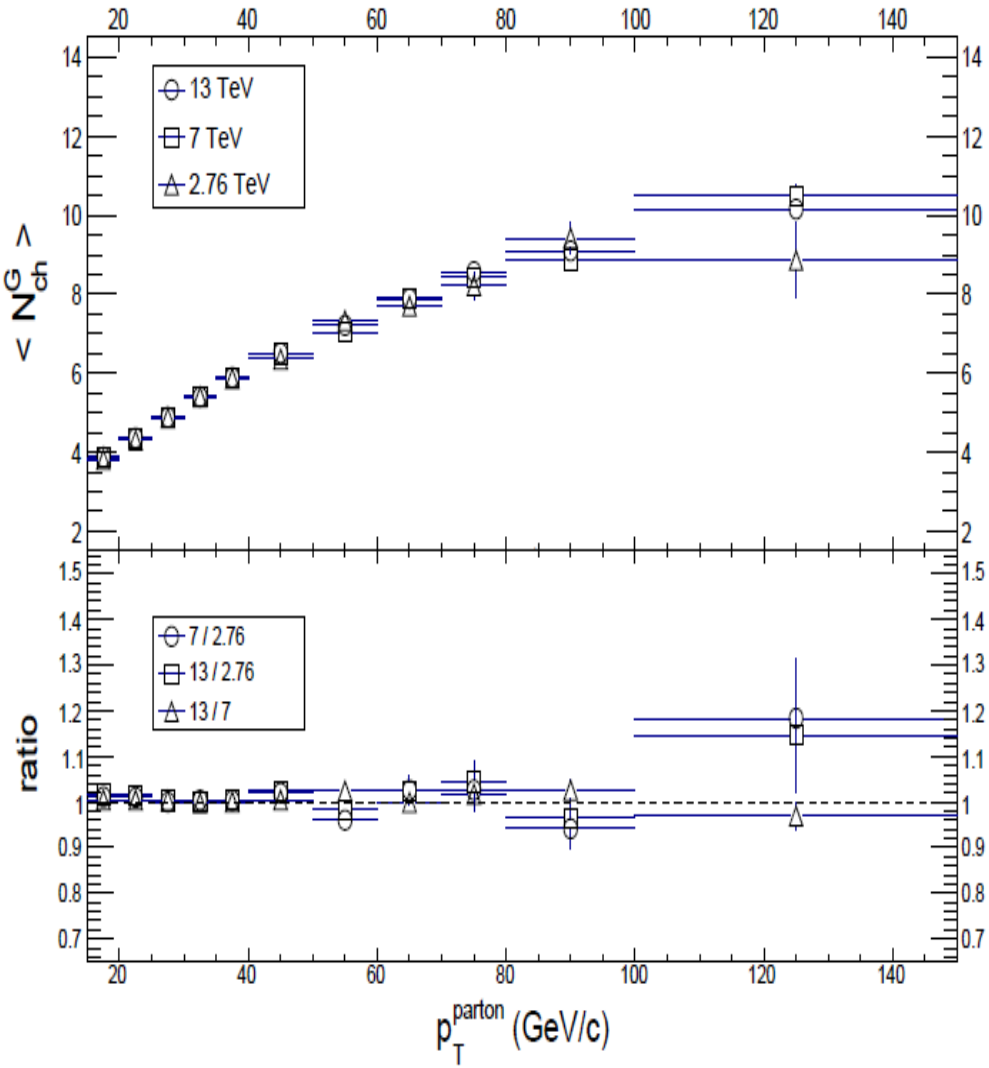
- <*R80*> decreases monotonically with parton p_T .
- It is more sensitive to the nature of parton, compared to the case of <*N*>.

Mean multiplicity distributions in charged jet

Quark-initiated jets

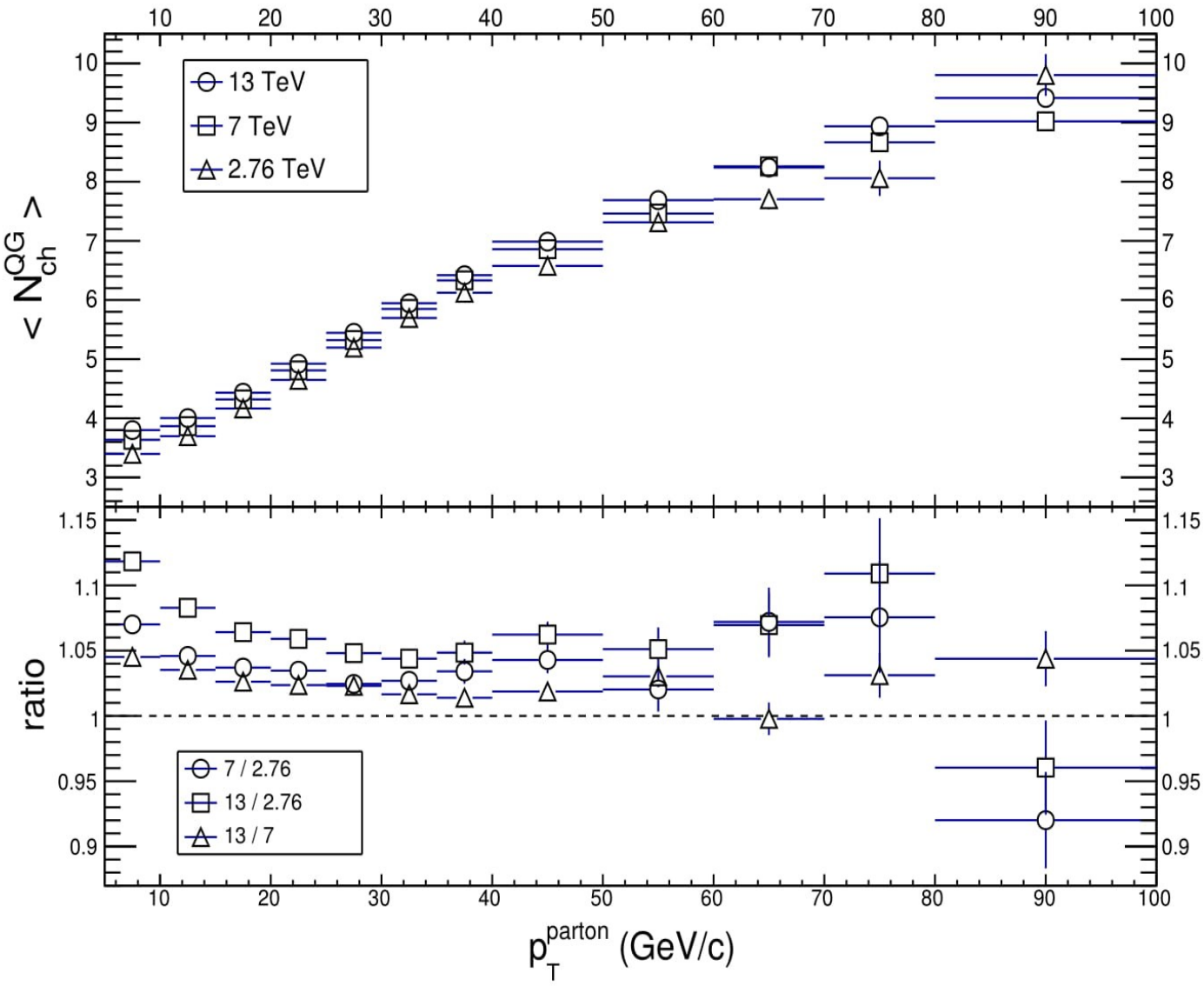


Gluon-initiated jets



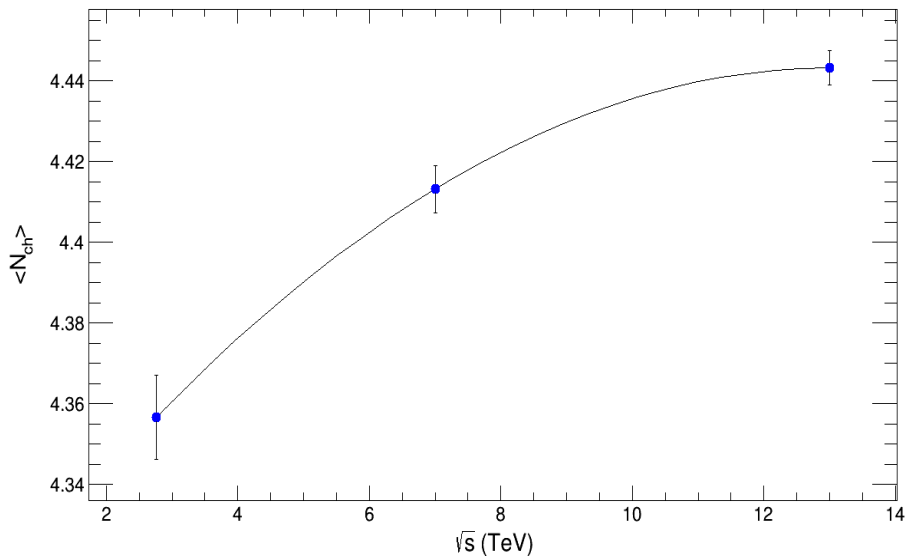
- $\langle N_{ch}^{Q} \rangle$ and $\langle N_{ch}^{G} \rangle$ are independent of $\sqrt{s}$.

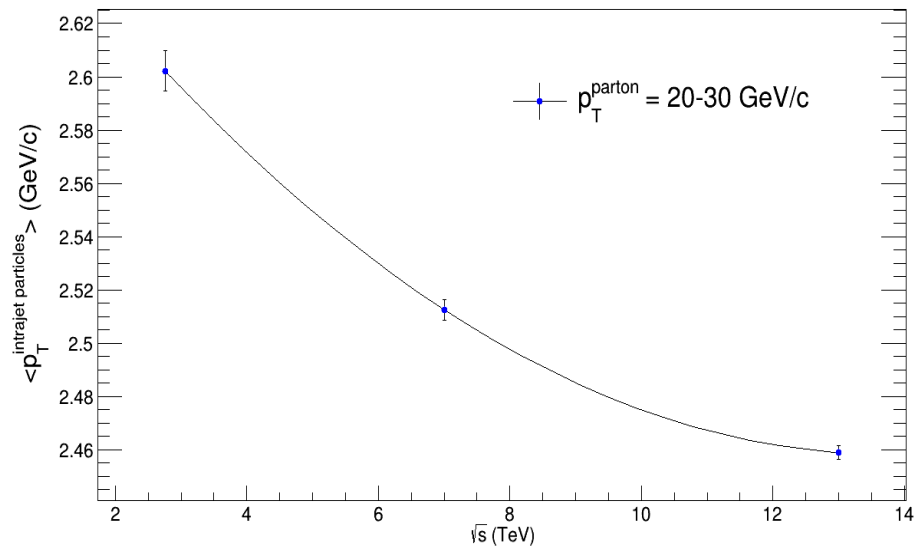
Mean multiplicity distributions in charged jet

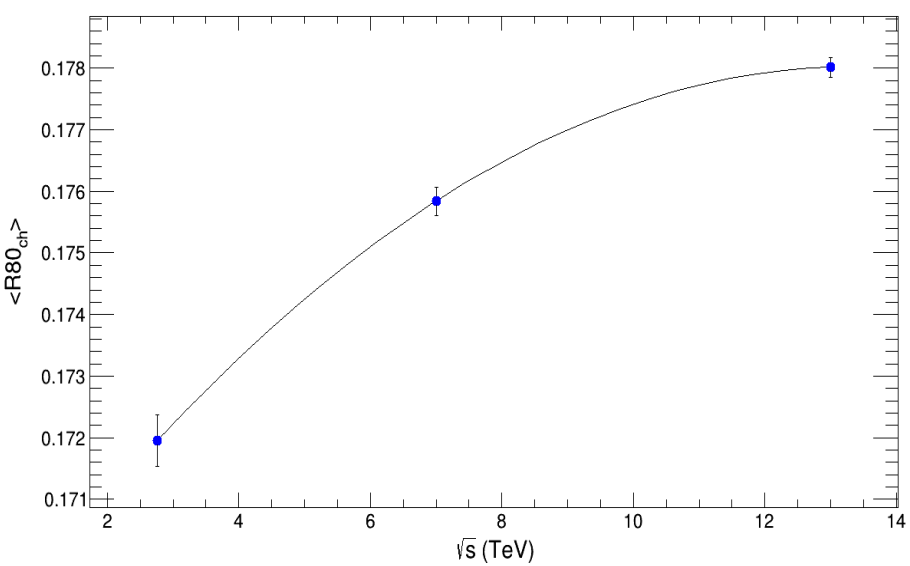


Mean multiplicity varies by ~5% when inclusive originating parton is considered

Evolution of $\langle N_{ch} \rangle$ and $\langle R80_{ch} \rangle$ with $\sqrt{s}$



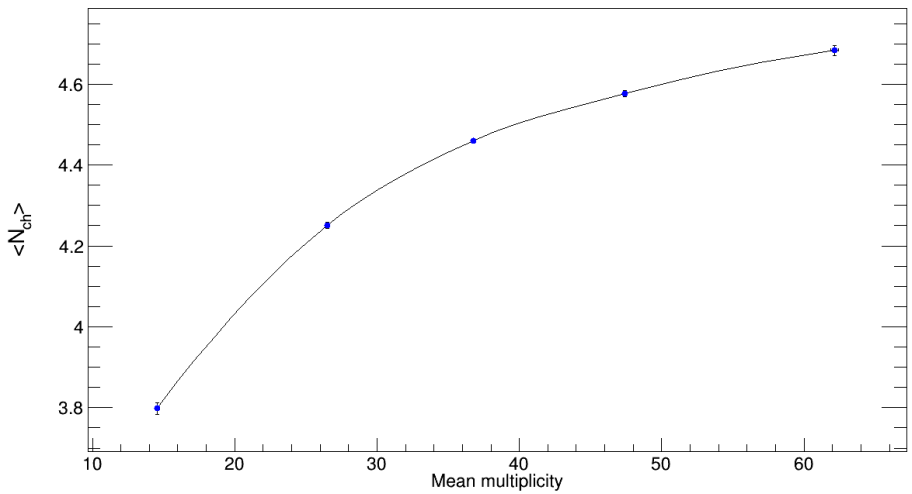


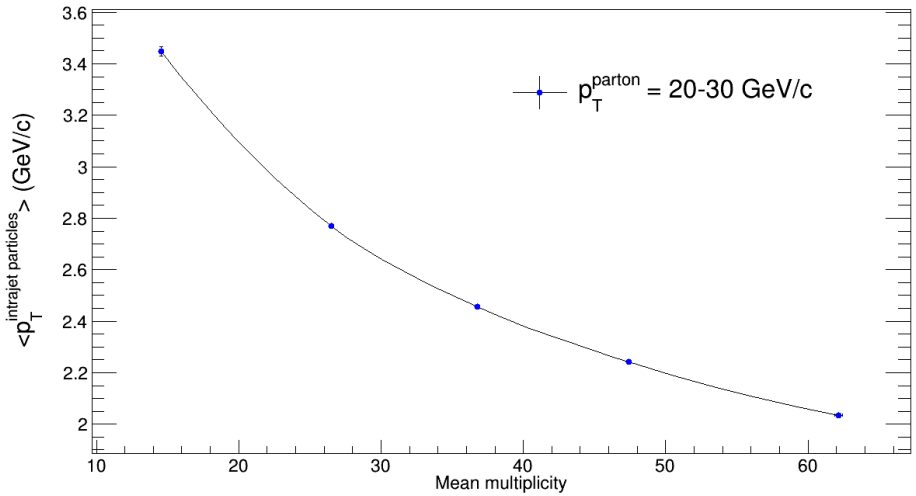


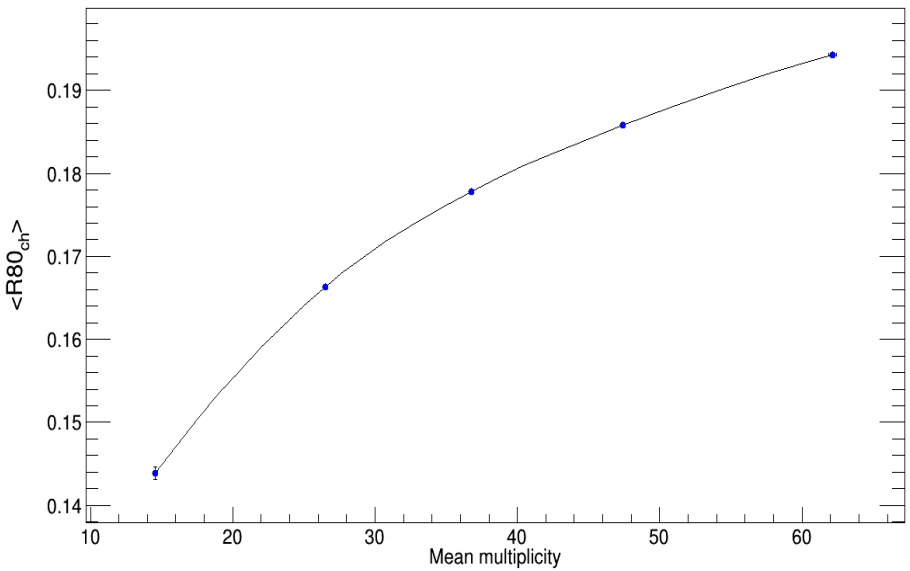
- $\langle N_{ch} \rangle$ and $\langle R80_{ch} \rangle$ increases with $\sqrt{s}$.
- $\langle p_T^{\text{intrajet particles}} \rangle$ decreases with increase in $\sqrt{s}$.
- For the change in $\sqrt{s}$ from 2.76 to 13 TeV, 2% change in $\langle N_{ch} \rangle$ and 3.5% change in $\langle R80_{ch} \rangle$ are observed.
- Indication of jet softening and broadening.

Evolution of $<N_{ch}>$, $<R80_{ch}>$ and $<p_T^{intrajet\ particles}>$ with multiplicity

Multiplicity bins : 0-1% (>55), 2-6% (43-55), 7-20% (33-42), 21-50% (22-32), 51-100% (<22)

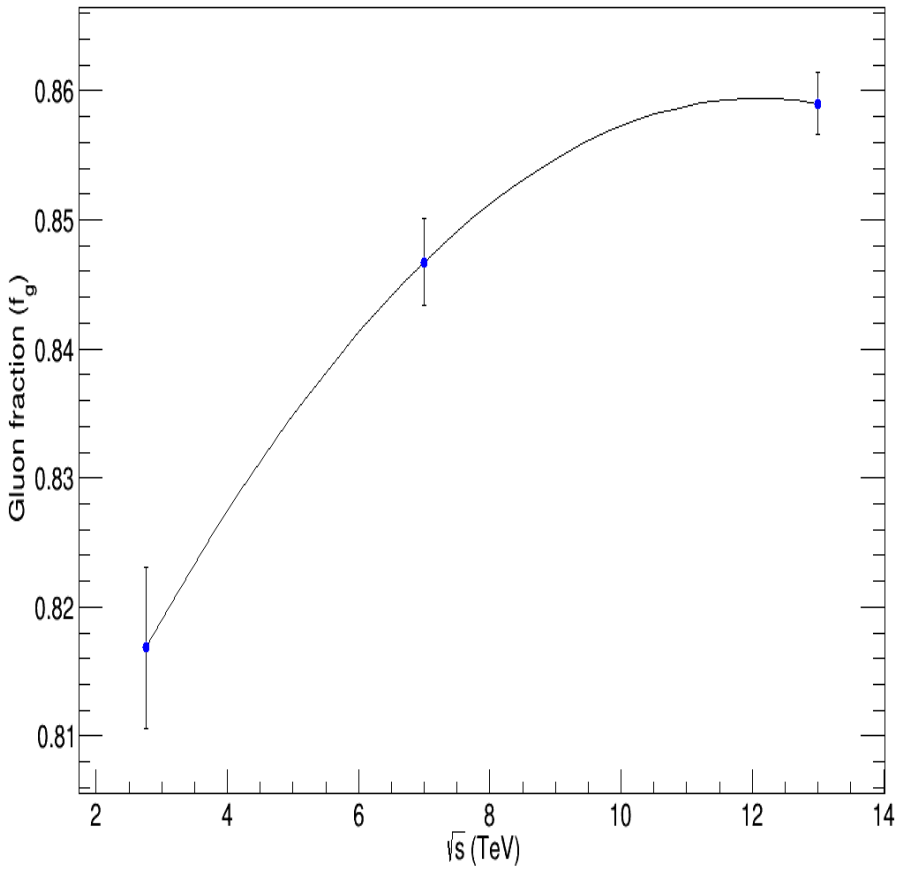


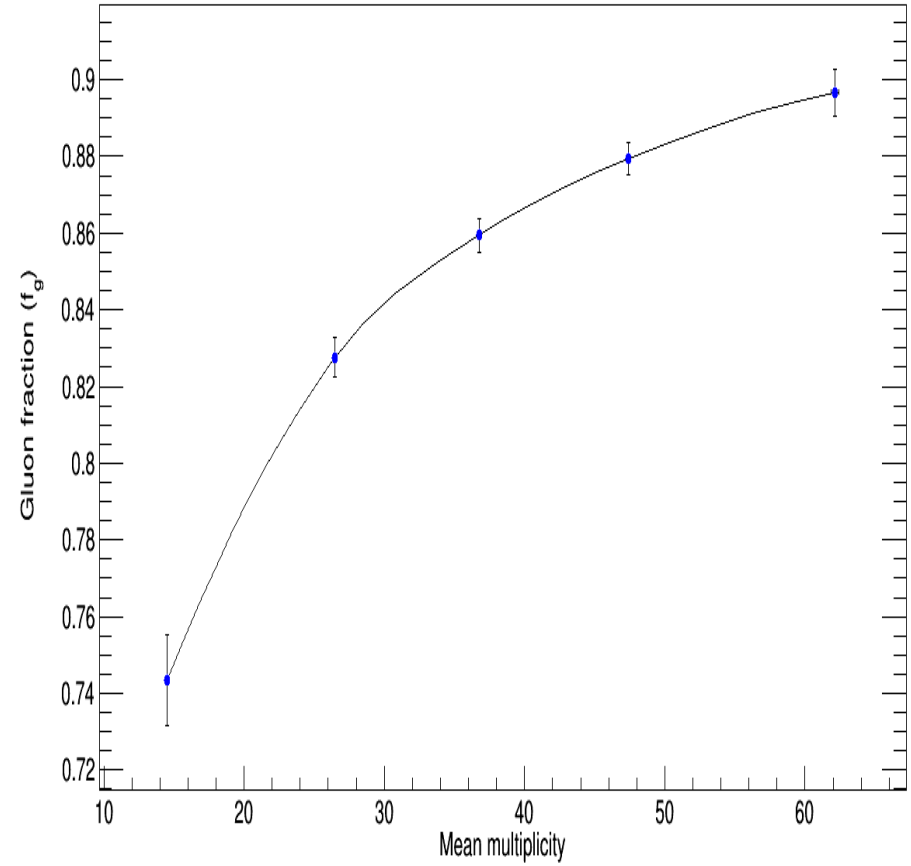




- $<N_{ch}>$ and $<R80_{ch}>$ increase while $<p_T^{intrajet\ particles}>$ decreases with increase in event multiplicity.
- For the change in mean event multiplicity from 14 to 62, 23% change in $<N_{ch}>$ and 35% change in $<R80_{ch}>$ are observed.
- Indication of jet softening and broadening.

Evolution of Gluon fraction (f_g) with √s and Multiplicity





- f_g increases with √s and multiplicity.
- 5% increase in f_g due to change in √s from 2.76 to 13 TeV.
- 20% increase in f_g due to change in mean event multiplicity from 14 to 62.
- The increase in gluon fraction can be accounted for the observed softening and broadening of inclusive jets with √s and event multiplicity.

Summary and conclusion

- We studied evolution of inclusive charged jet properties with $\sqrt{s}$ and multiplicity using PYTHIA.
- Fraction of gluon jets increases with $\sqrt{s}$ and multiplicity.
- The $\langle N_{ch} \rangle$ and $\langle R80_{ch} \rangle$ of the inclusive jets increase with $\sqrt{s}$ and multiplicity.
- $\langle p_T \rangle$ decreases with multiplicity.
- Increase in $\langle N_{ch} \rangle$ and $\langle R80_{ch} \rangle$ and decrease in $\langle p_T \rangle$ with multiplicity indicate softening and broadening of jets.
- The softening and broadening of the jets in PYTHIA can be attributed to increase in the gluon fraction with $\sqrt{s}$ and multiplicity.

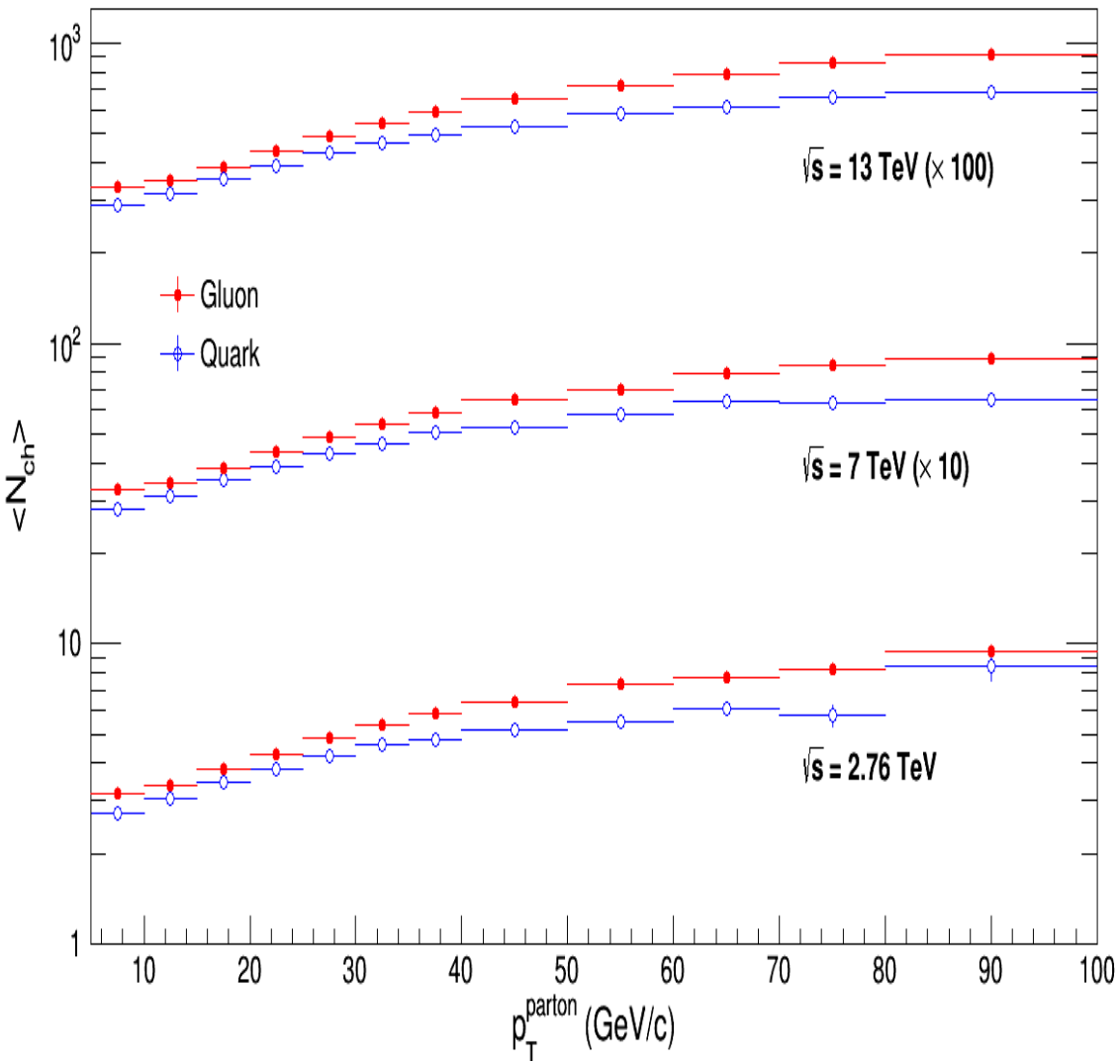
.... if jet modification observed at all experimentally in high multiplicity pp events ***.... a careful interpretation is required !!!***

Thanking.....

- Prattoy Das
- Abhi Modak
- Sidharth K. Prasad
- Supriya Das

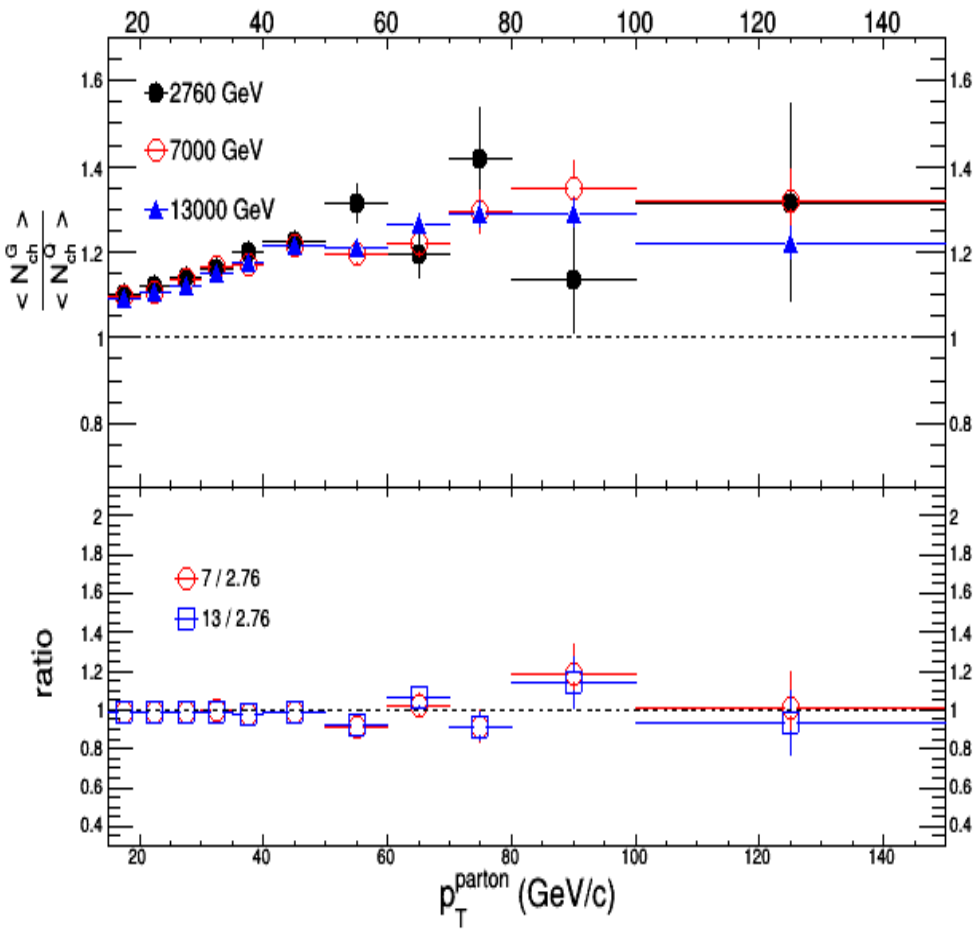
Back up

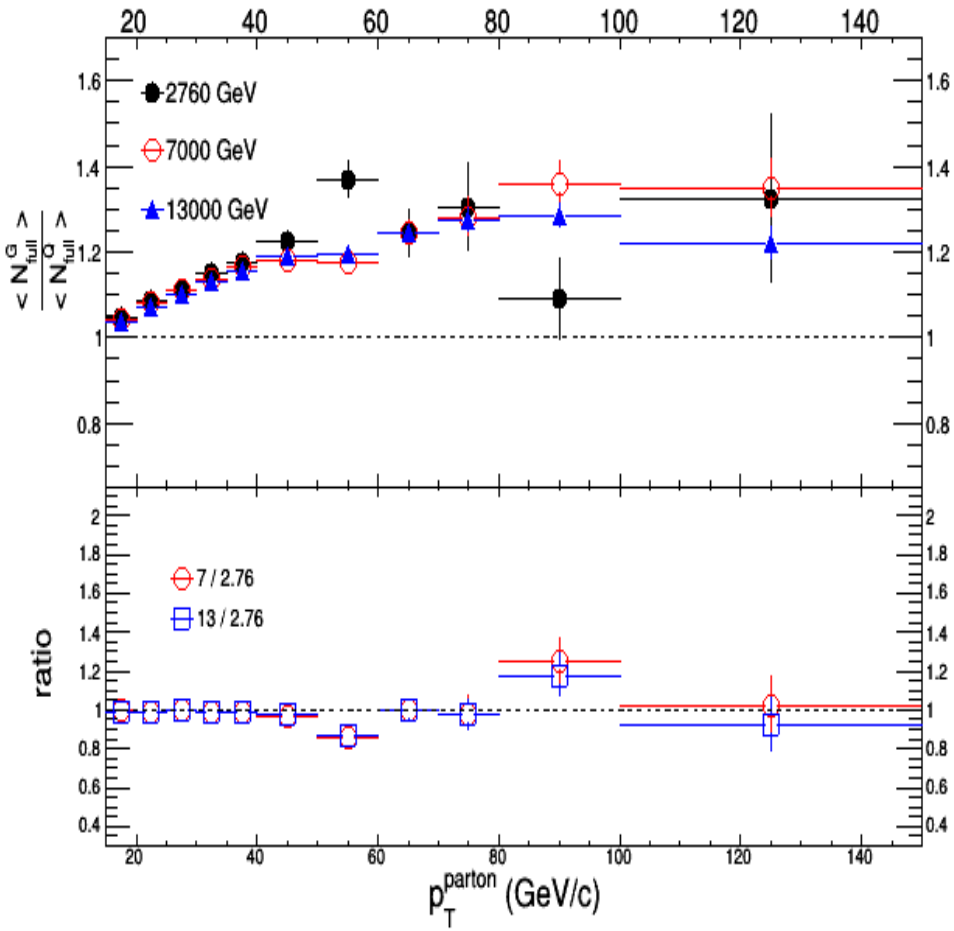
$\langle N_{ch} \rangle$ Vs p_T^{parton}



- Quark and gluon initiated jet show different properties.
- <Nch> is large for gluon jets.
- Inclusive jets contain both quark and gluon jets.
- Change in fraction of gluon jets will bring a change in the properties of inclusive jets.

Mean multiplicity distributions in charged and full jet





R_{80} distributions in charged and full jet