Cluster particle production @ SPD experiment

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Motivation

- Partons - products of hadron-hadron hard scattering are not accessible for direct measurement
- We can get an information about these particles from the final state products resulting from harmonization of quark-gluon shower created by the initial parton
- When the energy of parton-initiator is *high enough* in the final state a *jet* of particles will be formed, which will correspond to initial parton with high accuracy:

$$\mathbf{p^{Jet}\,(E,\,Px,\,Py,\,Pz)\;\approx\;p^{parton}\,(E,\,Px,\,Py,\,Pz)}$$

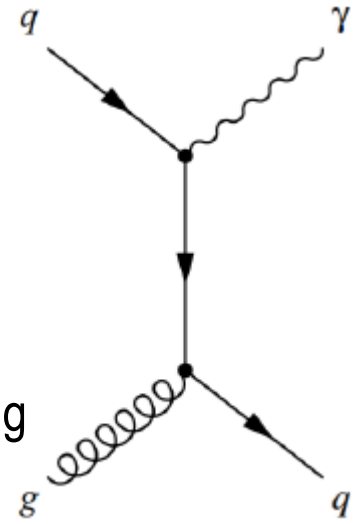
- Initial parton can exchange momentum with beam remnants and other partons
- If the energy/momentum of parton-initiator is *high enough* than the momentum of exchange, the jet can be associated with the parton.
- The goals of this study:
  - Understand the admissibility of such approximation for energies at NICA and SPD experiment
  - Study processes of parton production at energy region between non-pQCD and pQCD
  - Verification of parton fragmentation functions

What was done

- Kinematical properties of hard scattered partons and clustered jets was compared on generator level
- Estimation of magnetic field impact on jet reconstruction was made
- After taking into account magnetic field effects number of jets decreases in ~3 times and number of jets with leading charged particle also decreases
- It seems that clustered jets could be associated with initial parton even with magnetic field impact
- We expect enough statistics to make these analysis

https://indico.jinr.ru/event/3575/sessions/2093/#20230427

Event generation and jet reconstruction settings



- We use Pythia8 generator and FastJet package
- We generate process: $qg \rightarrow q\gamma$
- Energy of collisions $\sqrt{s} = 27$ GeV
- *anti-kt* algorithm with parameter R = 0.4, 0.6, 0.8 was used for jet clustering
- Minimum jet $p_T = 0.5GeV$
- Jet was clustered from final state particles with $p_T > 0.25$ GeV and $\eta < 5$
- Clustered jets are matched to hard scattered parton (status = 23)
- Hard scattered parton cuts: $p_{T,\,parton}$ >0 GeV, >3 GeV, >5 GeV (**gen information cut**)
- Jet should have at least two particles

Optimization of parameters

- We studied different cuts on observed parameters and compare clustering algorithms:
  - η regions: 0/0.5/1/1.5/2/3
  - Minimal jet p_T: 2, 2.5, 3, 3.5, 4, 4.5, 5
  - Minimal particle p_T: 0.25, 0.5, 0.75, 1
  - Anti-kt/Kt/CA algorithms with R = 0.4, 0.8, 1.2, 1.5
- **Different clustering algorithms find similar jets**
- Table with jet/parton p_T distributions properties:

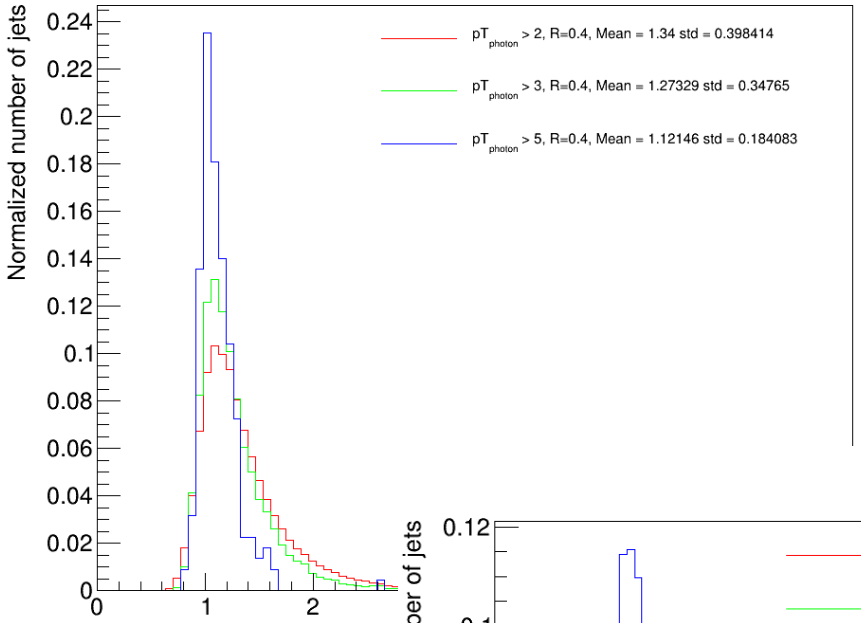
algorithm	mean	σ	σ/mean
Anti-kt, R=0.4	1.5466	0.4573	29.57
Kt, R=0.4	1.5513	0.4606	29.69
CA, R=0.4	1.5478	0.4583	29.61
Anti-kt, R=0.8	1.7480	0.5257	30.07
Kt, R=0.8	1.7478	0.5319	30.43
CA, R=0.8	1.7388	0.5250	30.19

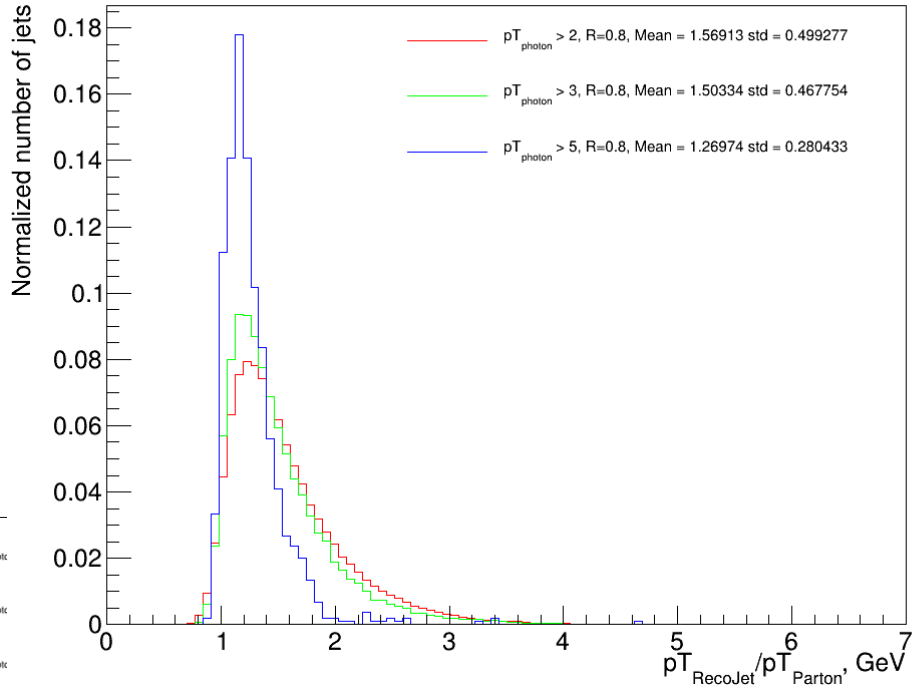
- The table was prepared for η from 0 to 3, $p_{T,jet} > 2$ GeV and $p_{T,particle} > 0.25$ GeV

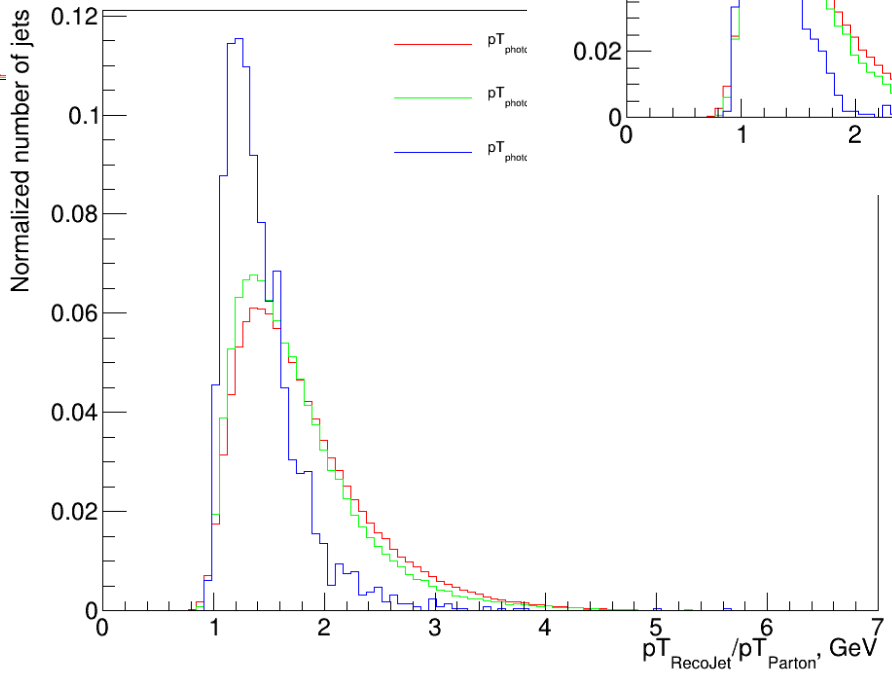
Event selections (without gen information)

- We use Pythia8 generator and FastJet package
- We generate process: $qg \rightarrow q\gamma$
- Energy of collisions $\sqrt{s} = 27$ GeV
- *anti-kt* algorithm with parameter R = 0.4, 0.8, 1.2 was used for jet clustering
- Minimum jet $p_T = 0.5 GeV$
- Jet was clustered from final state particles with $p_T > 0.25$ GeV and $\eta < 5$
- Clustered jets are matched to hard scattered parton (status = 23)
- Hard highest p_T **photon cuts**: $p_{T,\,photon}$ >2 GeV, >3 GeV, >5 GeV
- Photon and jet are back to back: $\Delta\varphi > 2.7$
- Jet should have at least two particles
- **Three approaches** for considered jets

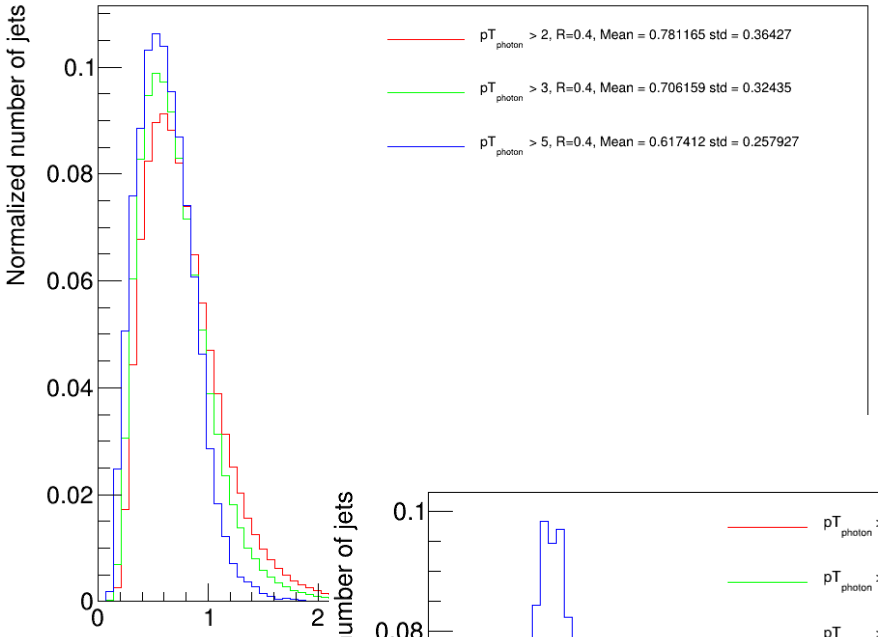
Clustered jet vs parton (leading jet before condition on photon)

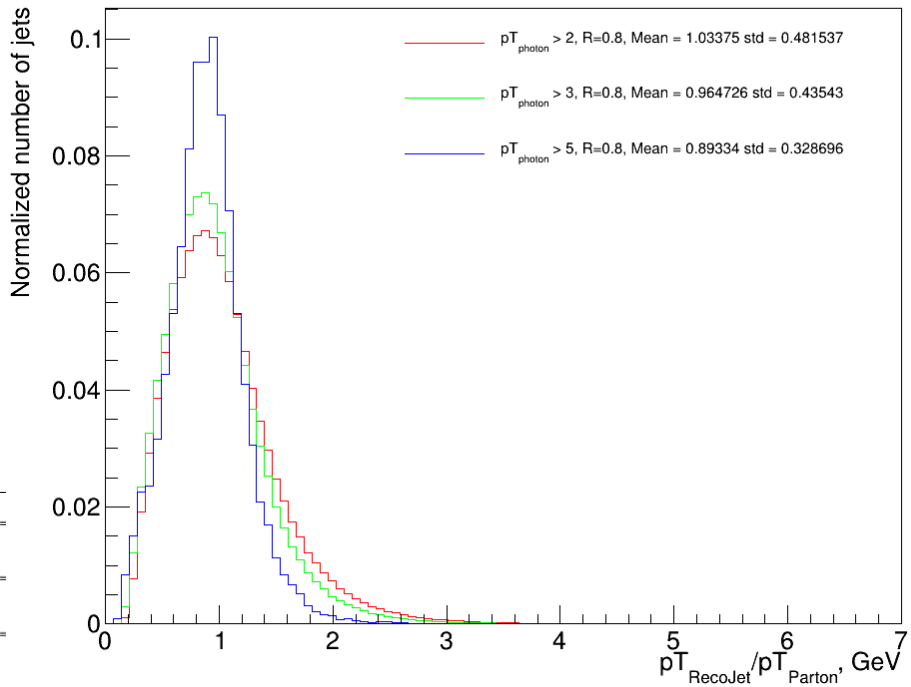


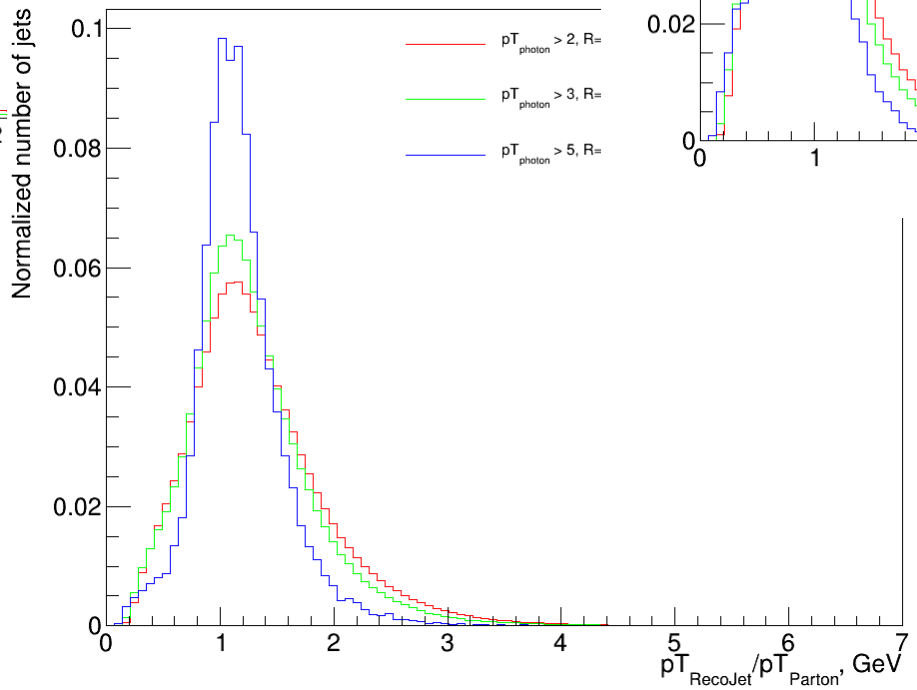




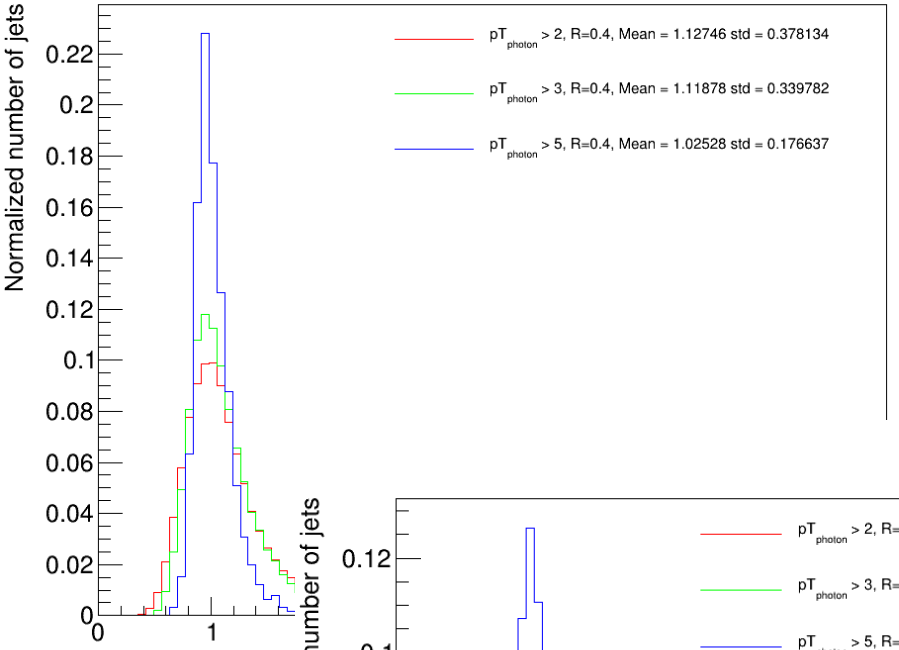
Clustered jet vs parton (leading “correct” jet)

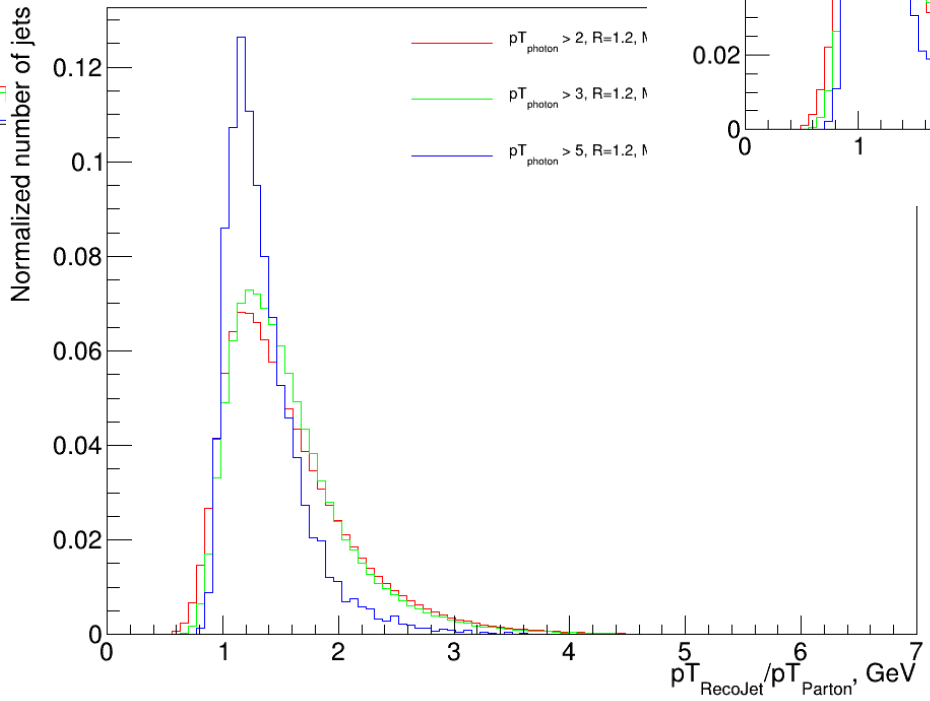


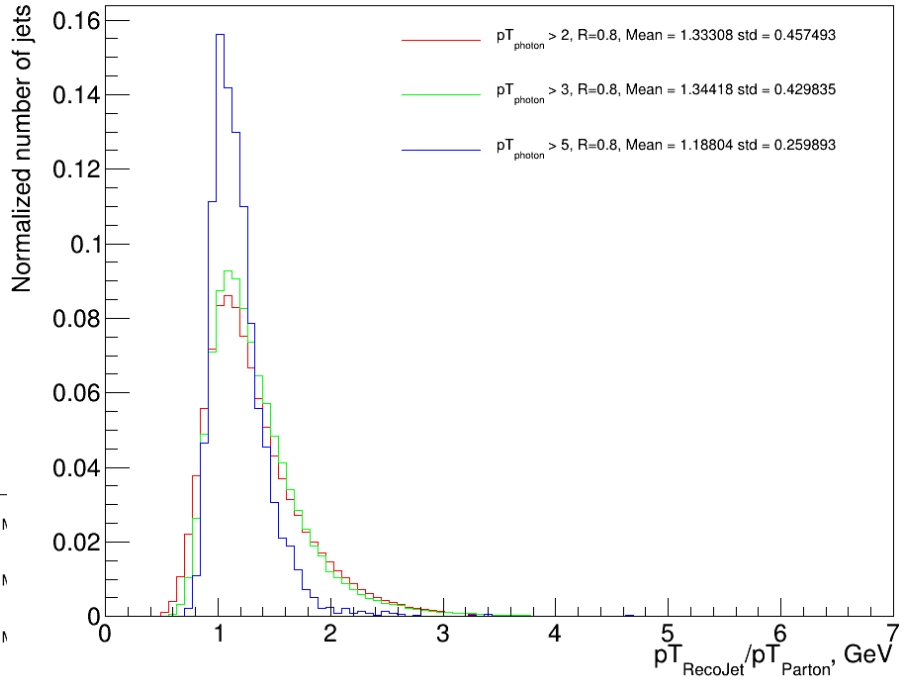




Clustered jet vs parton (leading “correct” jet with cut on jet p_T)

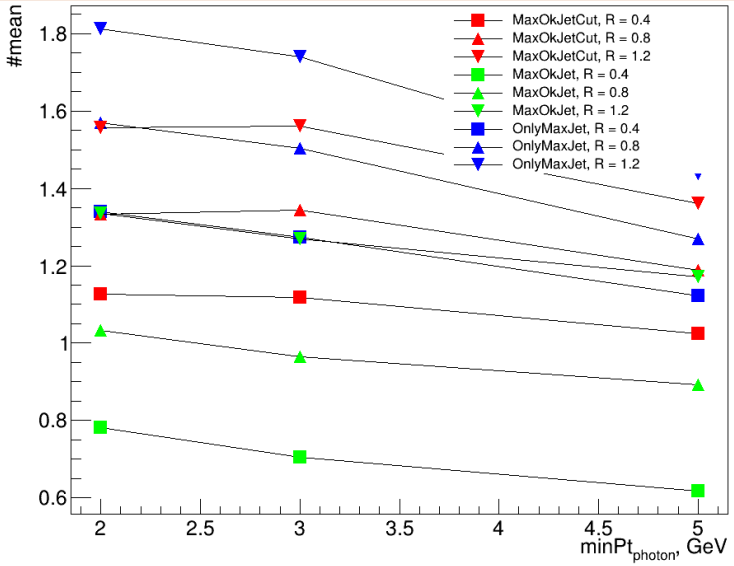


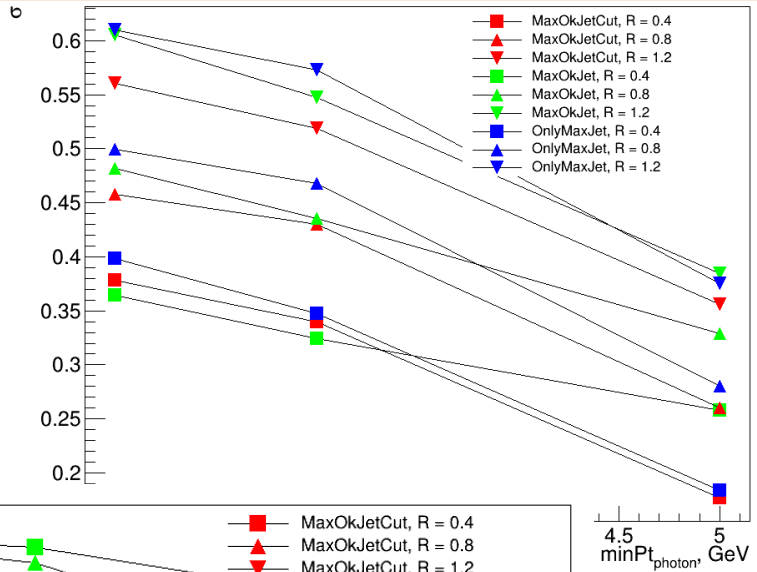


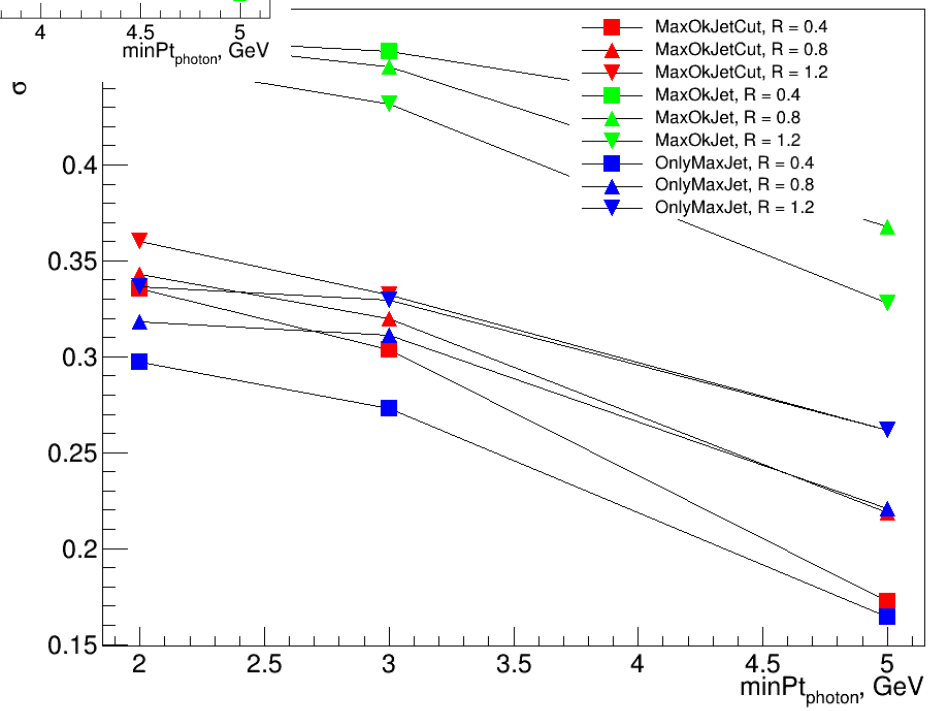


- Minimum jet p_T equals to minimal photon p_T

Mean values and σ







Sammary and plans

- Different clustering algorithms find similar jets, but we have to study time of their work

- We studied cuts on the photon:
  - Increasing radius parameter of clustering algorithm worsen parton-jet association
  - It is necessary to use cut on $p_{T,jet}$ together with cut on photon

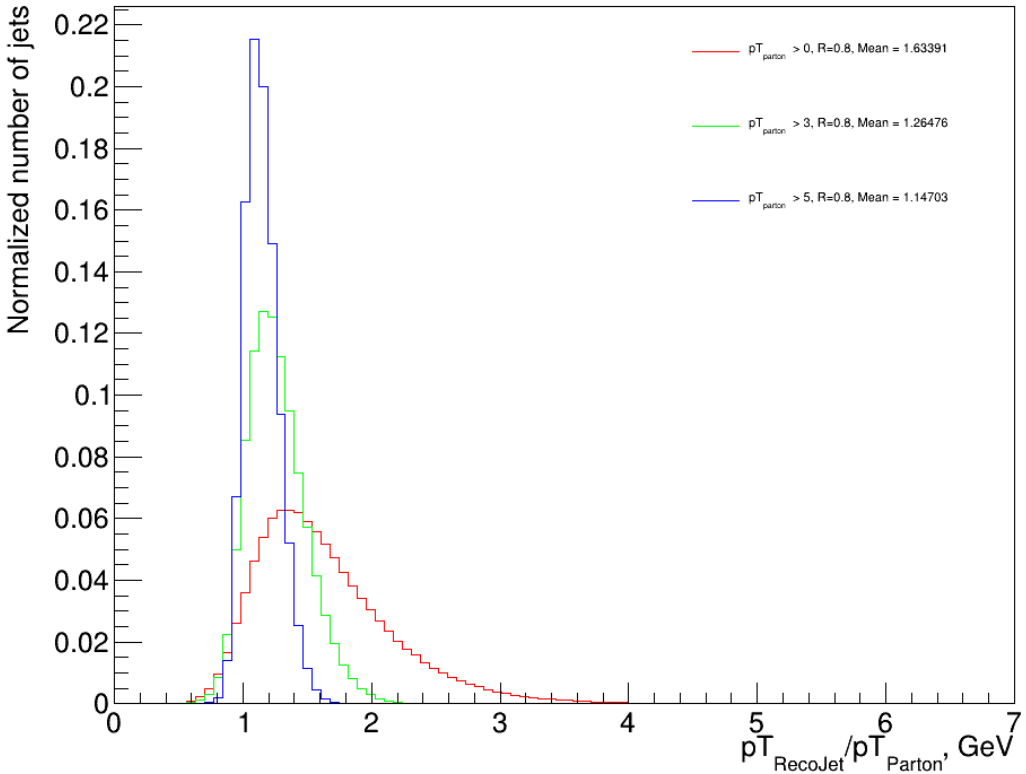
- Plans:
  - Analyzing of inclusive jet production
  - Check additional approaches to find clusters of particles
  - Repeat this study with full simulation of detector

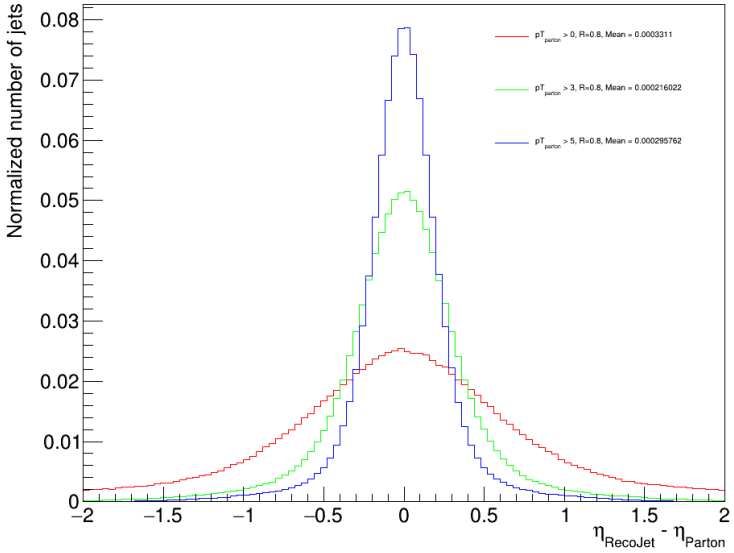
Back up

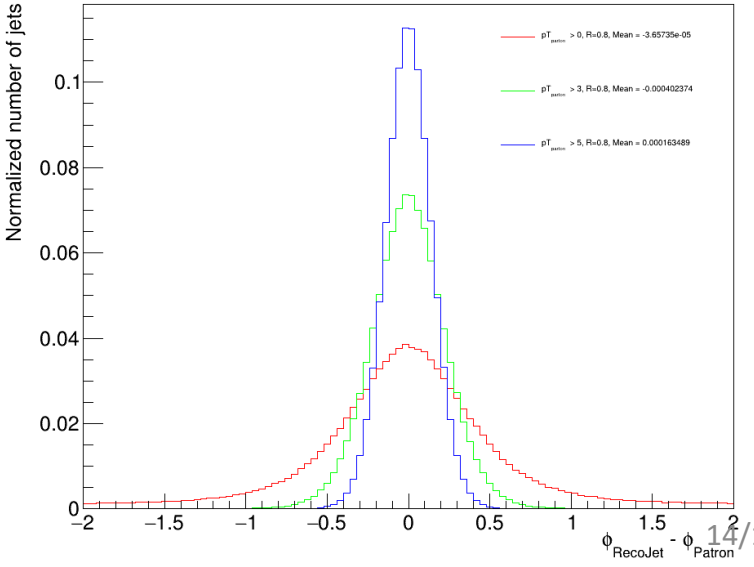
Objects definition

- Clustered jets:
  - Clustering algorithms can find many jet-like objects in single event
  - But we want to choose only objects, which could be associated with initial parton
  - We use two methods based on gen information to find such objects
    - We take all jets, which are found by clustering algorithm and select the closest one by distance (η,φ) to hard scattered parton, but the distance should be less than R
    - We take highest p_T jet and check, at least one jet constituent originated from hard scattered parton
  - Both methods give similar results

Clustered jet vs parton (R=0.8)

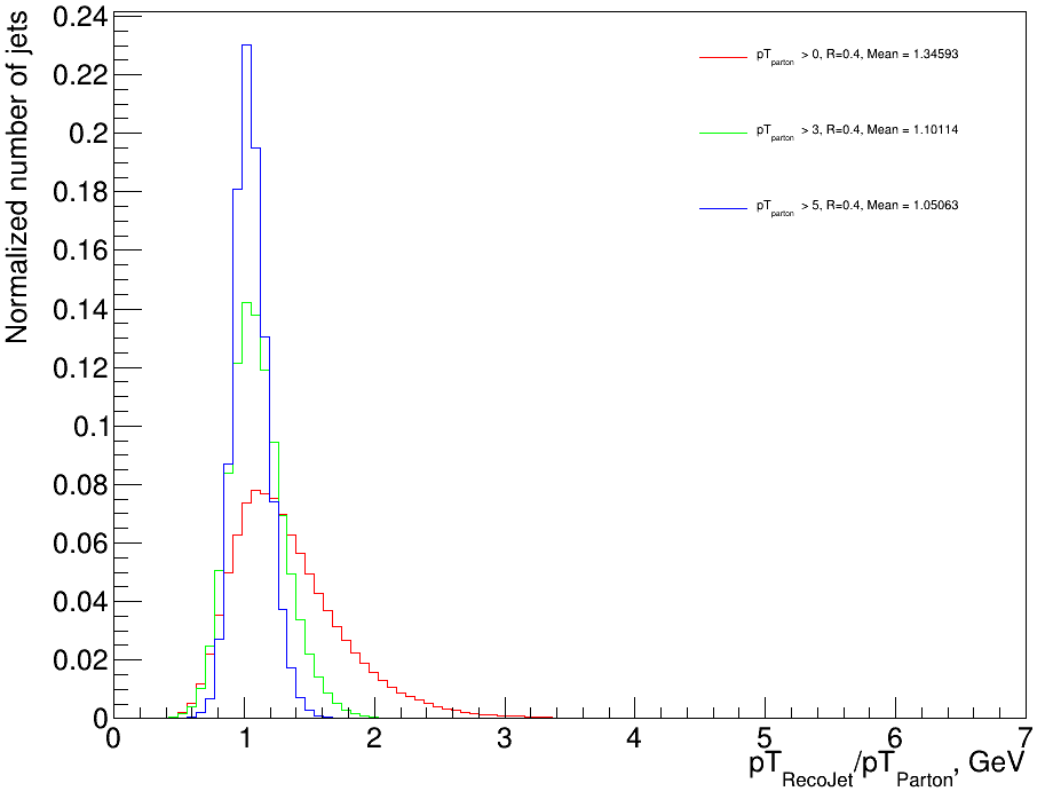


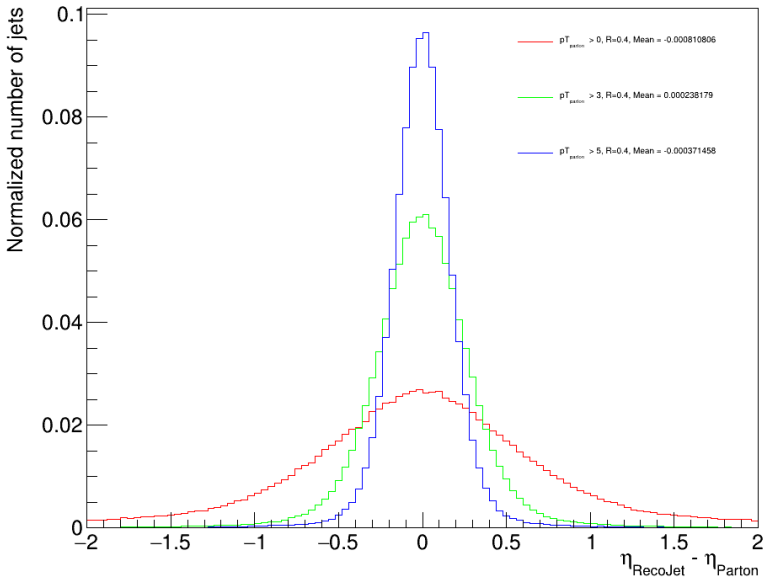


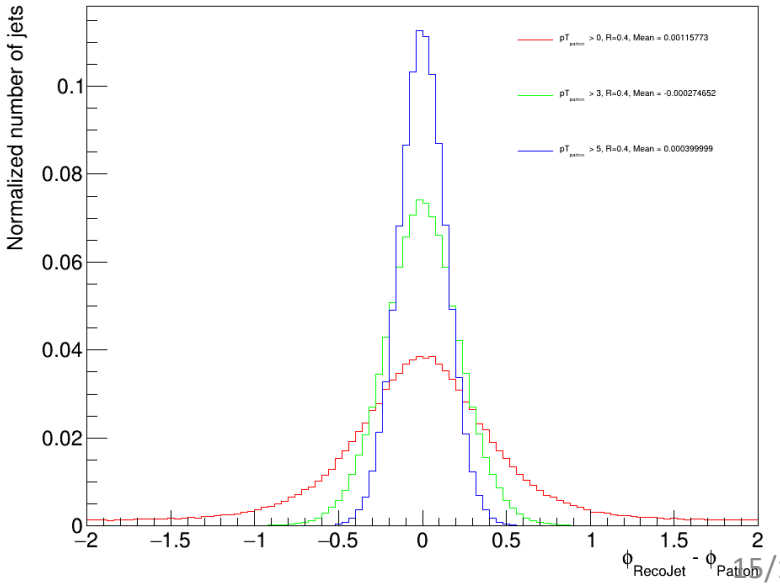


- Jet properties have good agreement with properties of initial parton

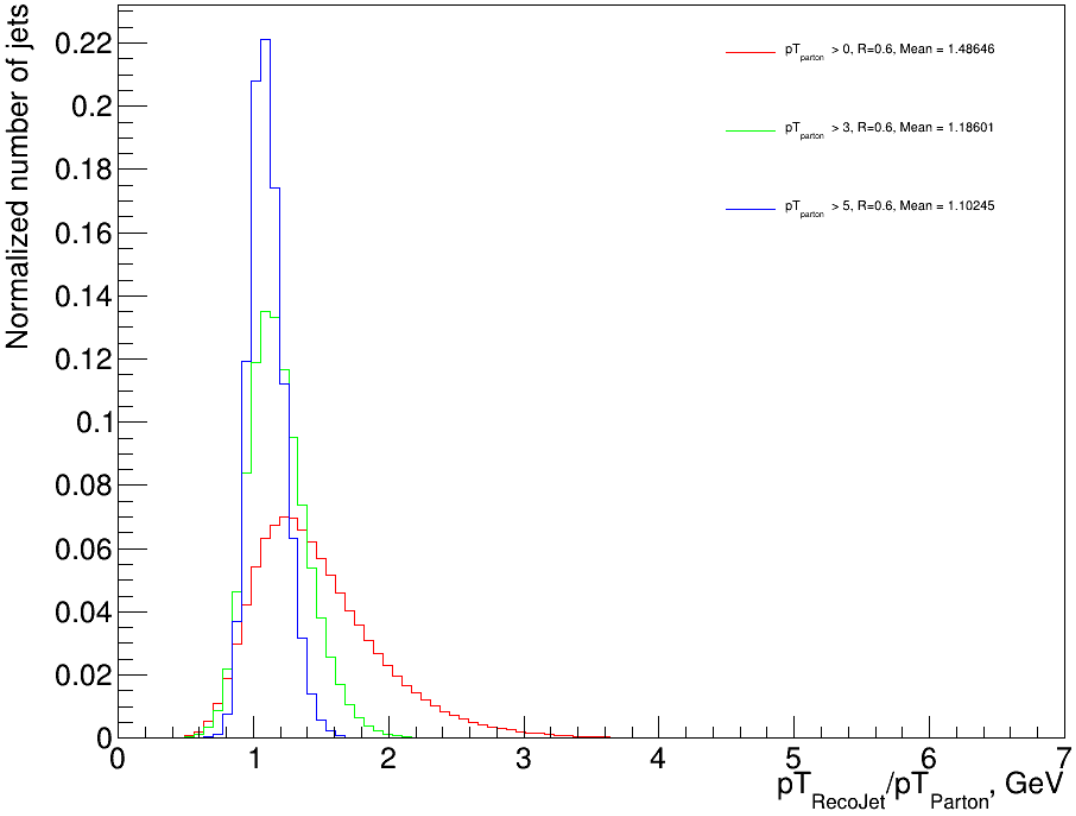
Clustered jet vs parton (R=0.4)

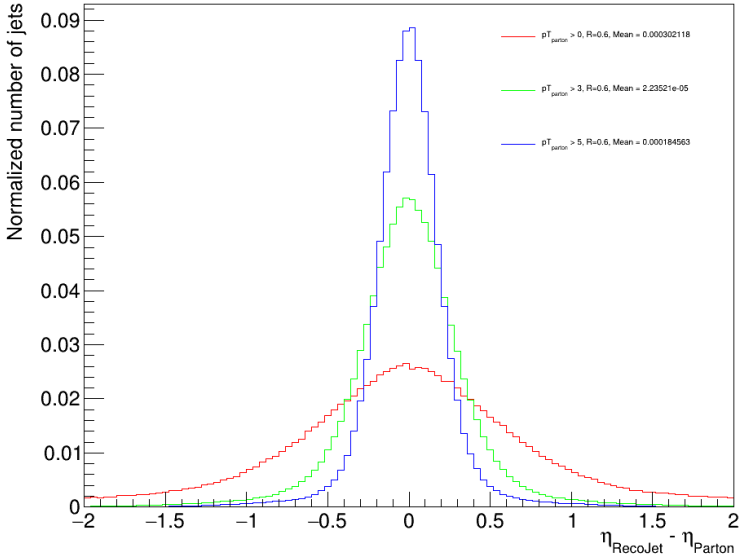


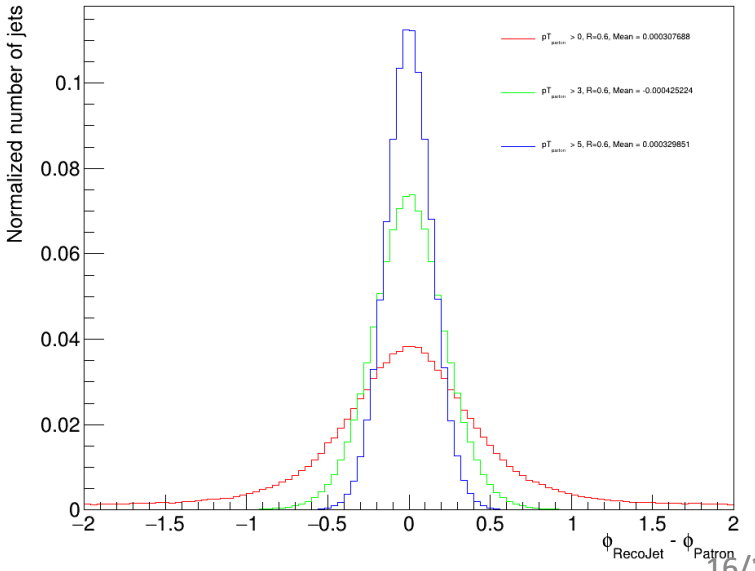




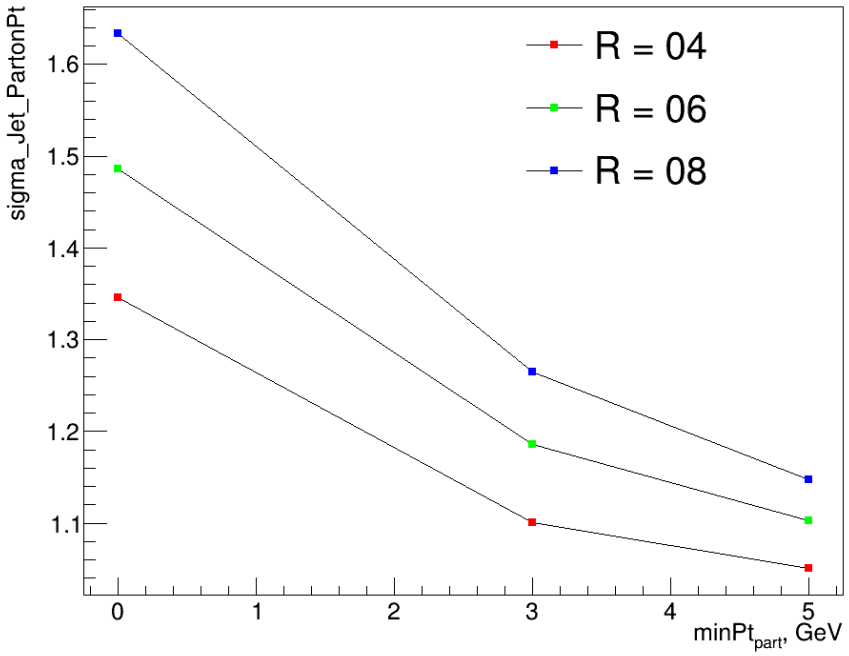
Clustered jet vs parton (R=0.6)

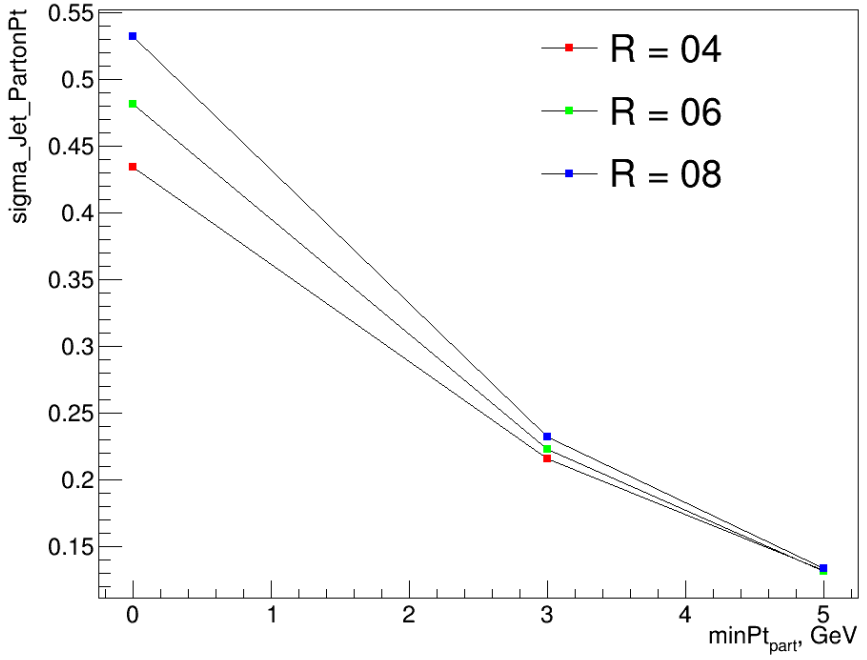






Mean values and σ





- High p_T partons produce jets, which could be better associated with them