

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
- If the energy of parton-initiator is high in the final state a *jet* of particles will be formed, which will correspond to initial parton
- The goals of this study:
 - Understand the admissibility of such approximation at low energies
 - Study processes of parton production at energy region between non-pQCD and pQCD

Jets at low energies in other experiments

- Jets at low energies was studied in 70s-80s in many experiments: PETRA, SFM 412, Pisa–Stony Brook, AFS etc.
- Since there was not good enough clustering algorithms, single high p_T hadrons and clusters of particles were considered as jets
- Main idea of those experiments was in confirmation of events with jets and measurement cross sections

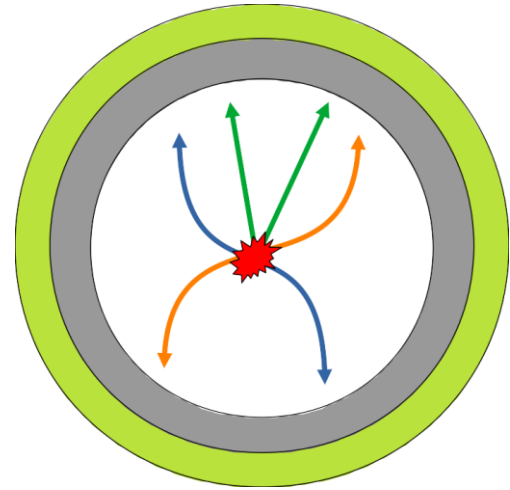
<https://inspirehep.net/literature/179516>

<https://inspirehep.net/literature/153610>

<https://inspirehep.net/literature/100764>

<https://inspirehep.net/literature/188734>

Problem statement



Performance of reconstruction for particles clustered production

- Search for clustered production of particles (efficiency)
- Reconstruction of parton-initiator kinematics depending on reconstructed jet characteristic
- Reconstruction of parton-initiator flavour depending on reconstructed jet characteristic

Clustering algorithms and parameters

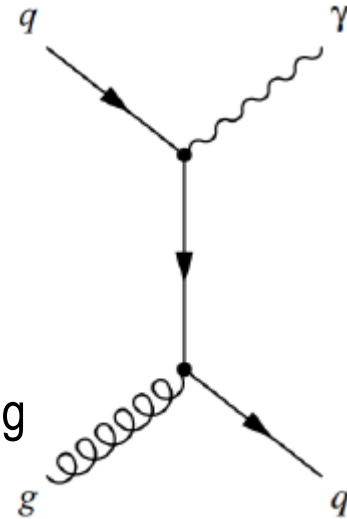
- Cluster/Jet reconstruction algorithm (Iterative Cone, kT, Anti-kT, Cambridge-Aachen, etc.)
- Radius parameter
- Inputs of clustering algorithms as objects of reconstruction and their kinematic thresholds
- Energy/momentum of reconstructed cluster

Objects definition

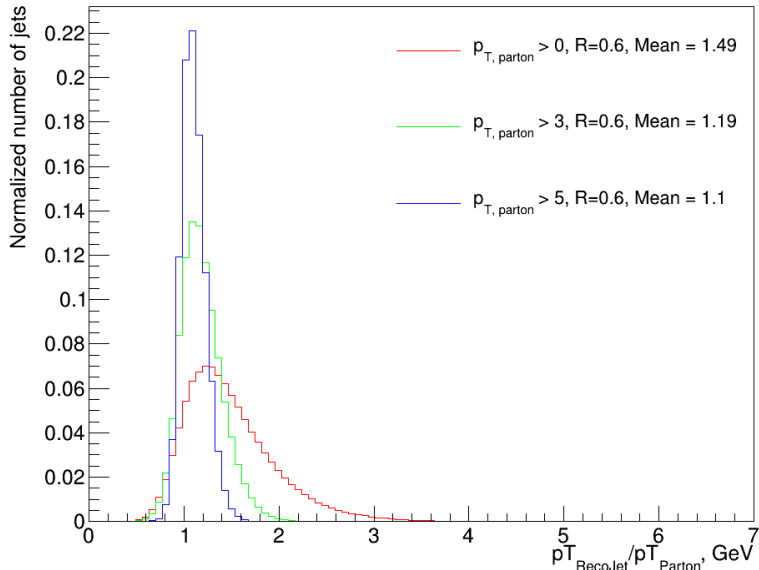
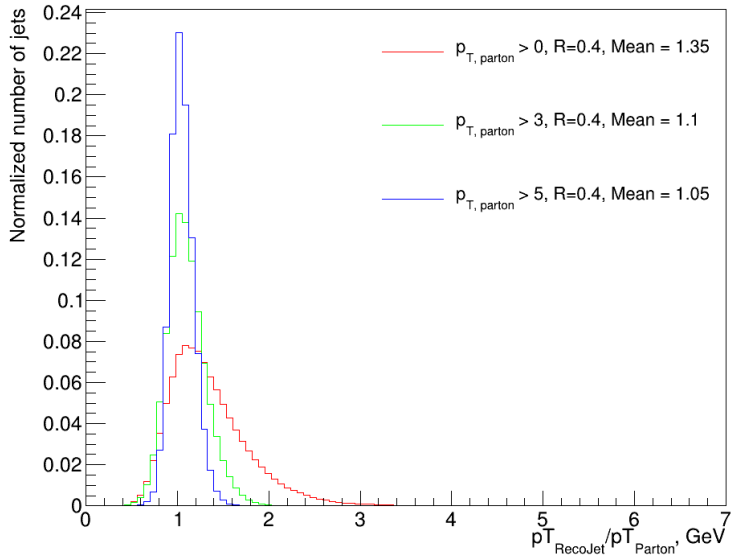
- Clustering algorithms can find many jet-like objects in single event
- But we want to choose only objects, which could be associated with initial parton
- Clustered jets (with gen information)
 - We take leading p_T jet and check, at least one jet constituent originated from hard scattered parton
- Clustered jets (only observable parameters)
 - We take leading p_T jet, but skip the jet with leading photon among jet constituents

Event generation and jet reconstruction settings (with gen information)

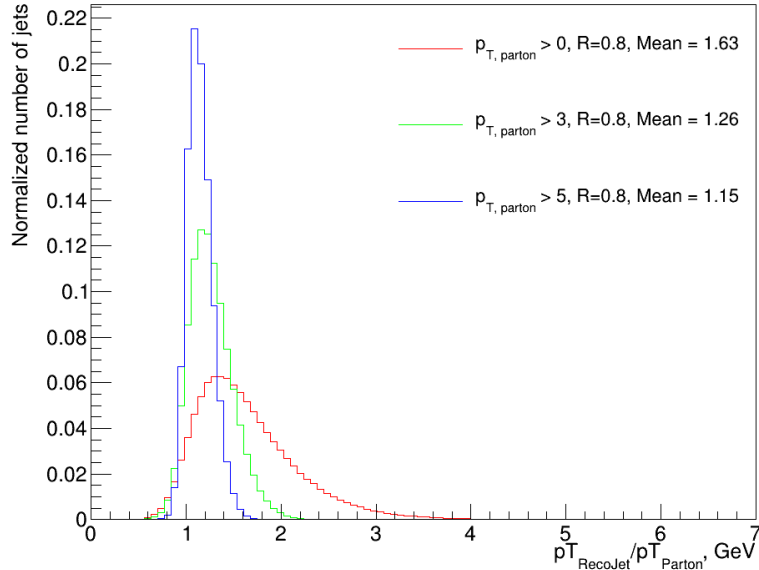
- We use Pythia8 generator and FastJet package
- We generate process: $qg \rightarrow q\gamma$
- Energy of collisions $\sqrt{s} = 27$ GeV
- *anti-kt* algorithm with parameter $R = 0.4, 0.6, 0.8$ was used for jet clustering
- Minimum jet $p_T = 0.5$ GeV
- Jet was clustered from final state particles with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



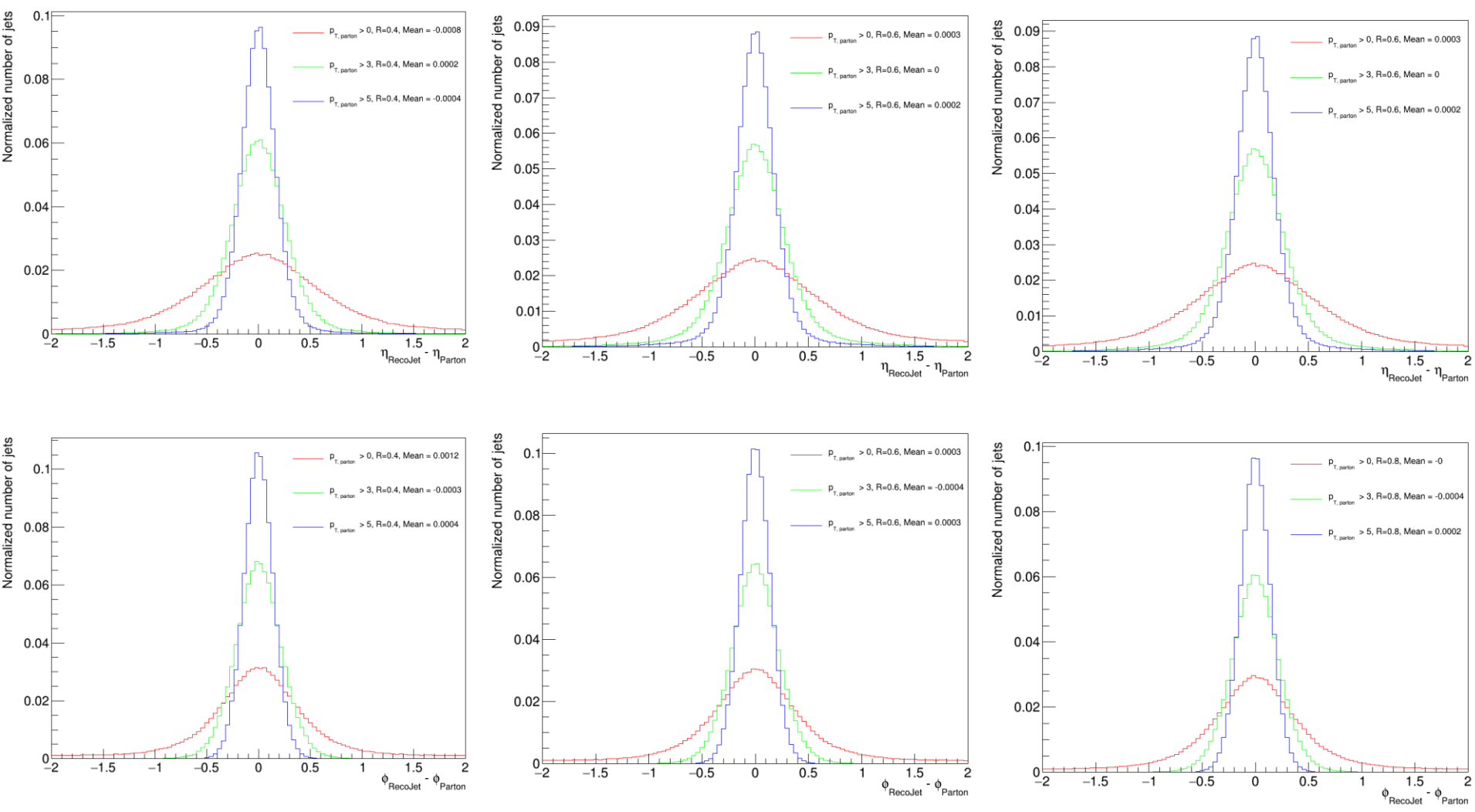
Clustered jet p_T vs parton p_T



- Partons with higher p_T produce jets, which better associated with them

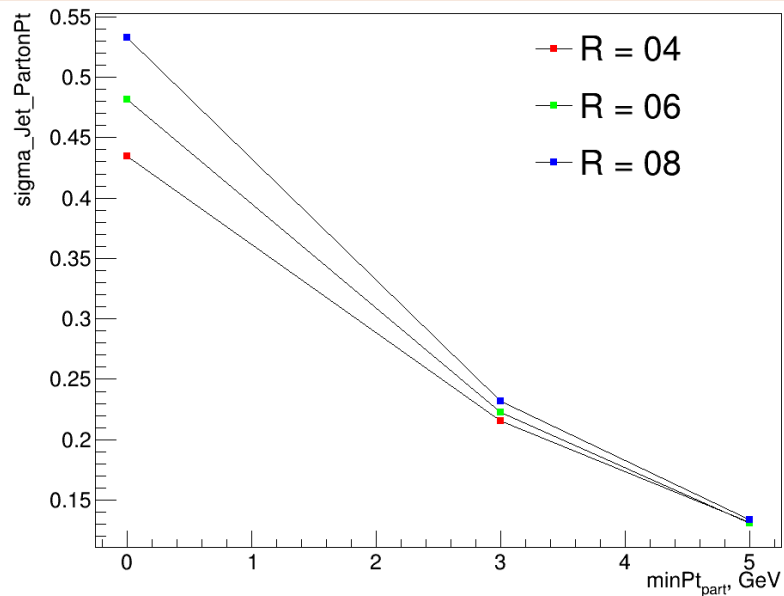
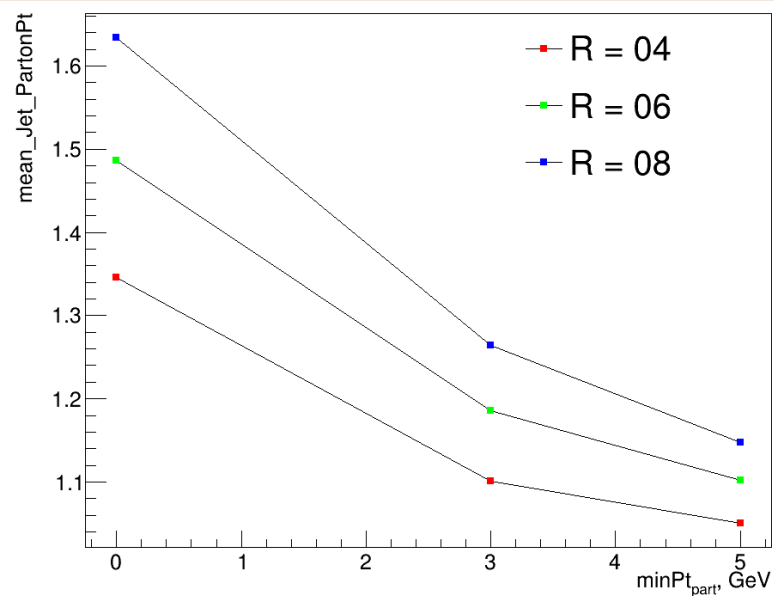


Clustered jet (φ, η) vs parton (φ, η)

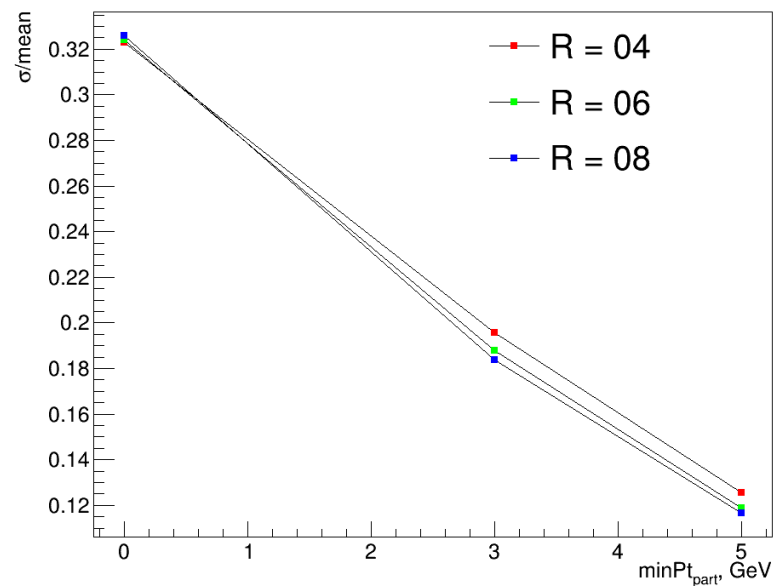


■ Jets and partons moves in the same direction

Mean values and σ



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



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**

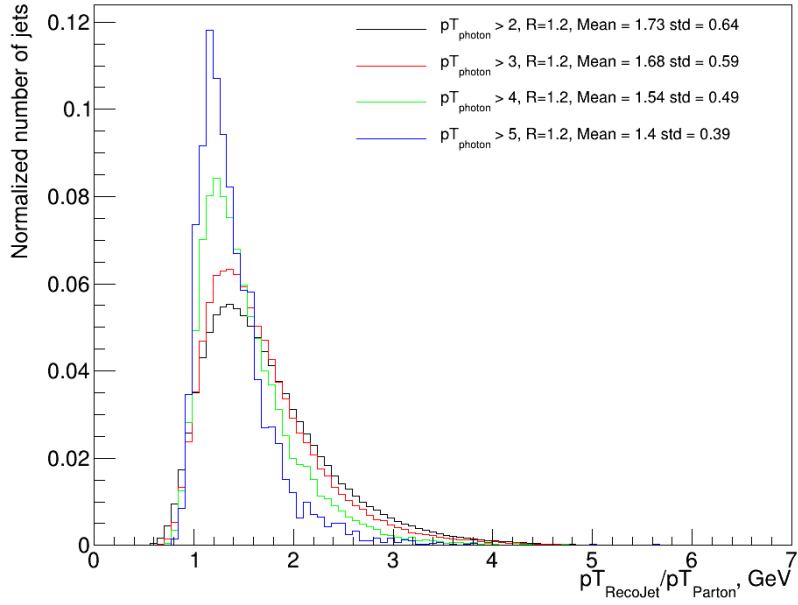
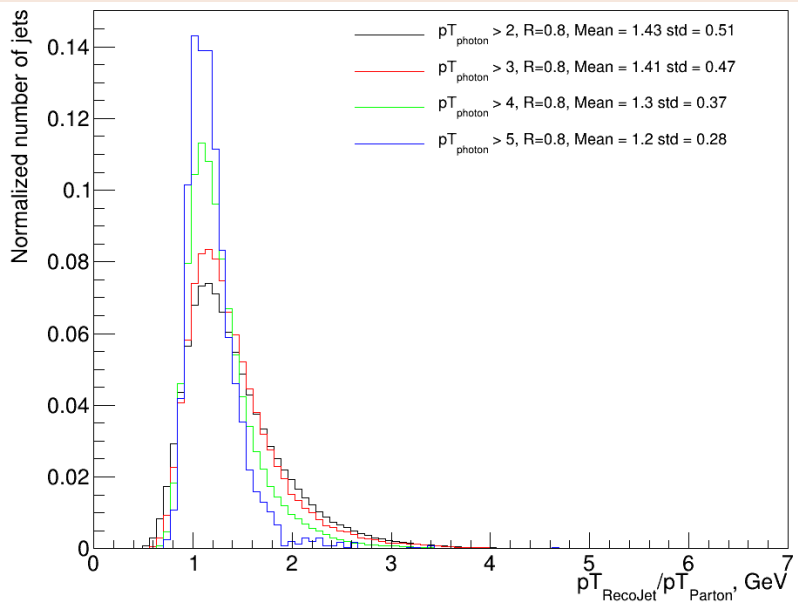
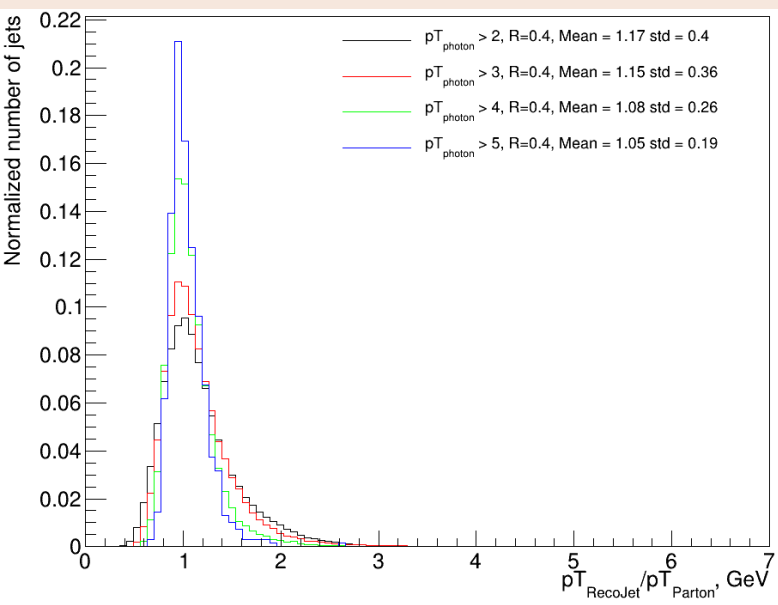
algorithm	mean	σ	σ / mean
Anti-kt, R=0.4	1.5466	0.4573	29.57
Kt, R=0.4	1.5513	0.4606	29.69
CA, R=0.4	1.5478	0.4583	29.61
Anti-kt, R=0.8	1.7480	0.5257	30.07
Kt, R=0.8	1.7478	0.5319	30.43
CA, R=0.8	1.7388	0.5250	30.19

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

Event selections (only observable parameters)

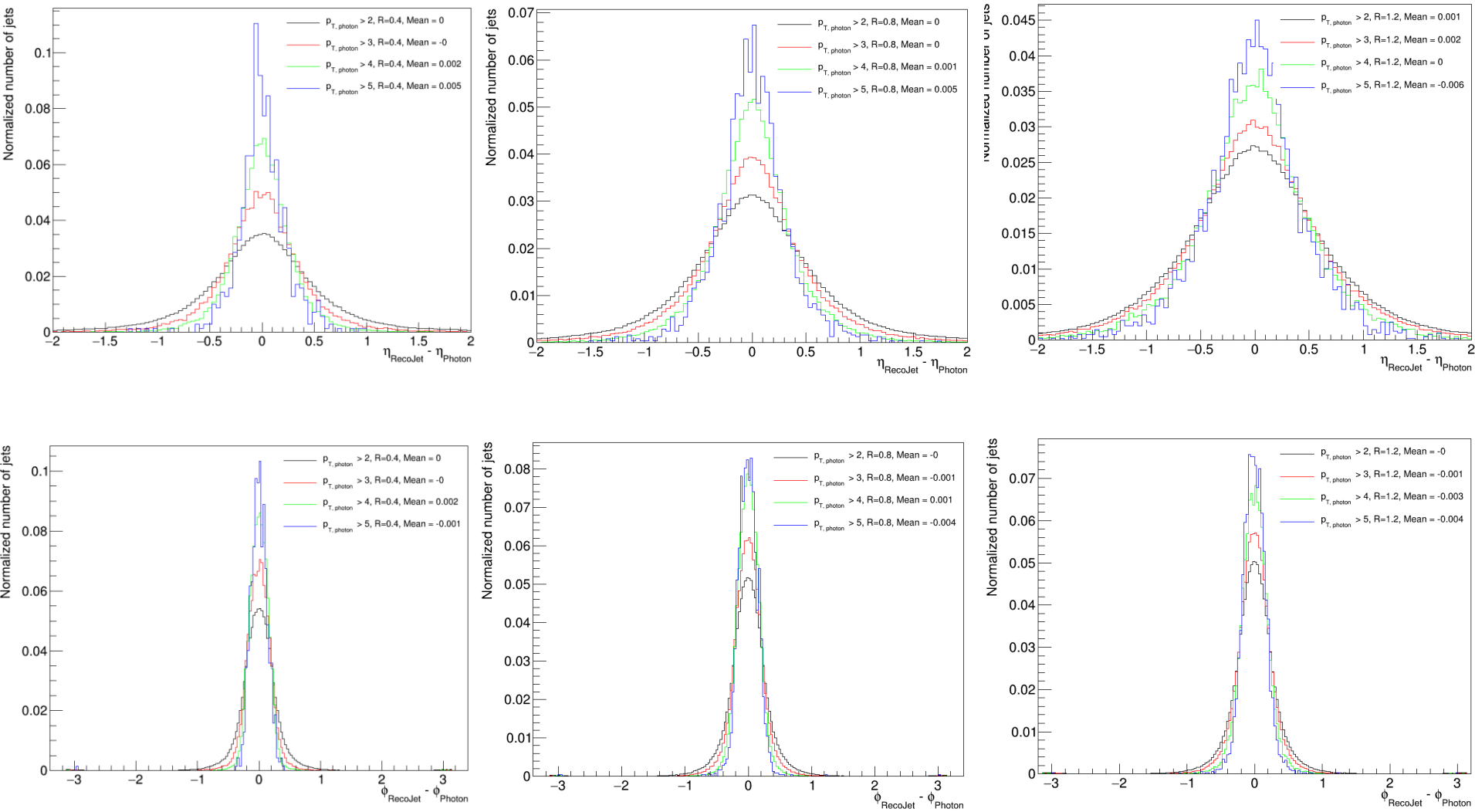
- We use Pythia8 generator and FastJet package
- We generate process: $qg \rightarrow q\gamma$
- Energy of collisions $\sqrt{s} = 27$ GeV
- *anti-kt* algorithm with parameter $R = 0.4, 0.8, 1.2$ was used for jet clustering
- Jet was clustered from final state particles with $p_T > 0.25$ GeV and $\eta < 5$
- Clustered jets are matched to hard scattered parton (status = 23)
- Leading photon p_T cuts: $p_{T, photon} > 2$ GeV, > 3 GeV, > 4 GeV, > 5 GeV
- Leading jet p_T cuts: $p_{T, jet} > 2$ GeV, > 3 GeV, > 4 GeV, > 5 GeV.
- Photon and jet are back to back: $\Delta\varphi > 2.7$
- Jet should have at least two particles

Clustered jet p_T vs parton p_T



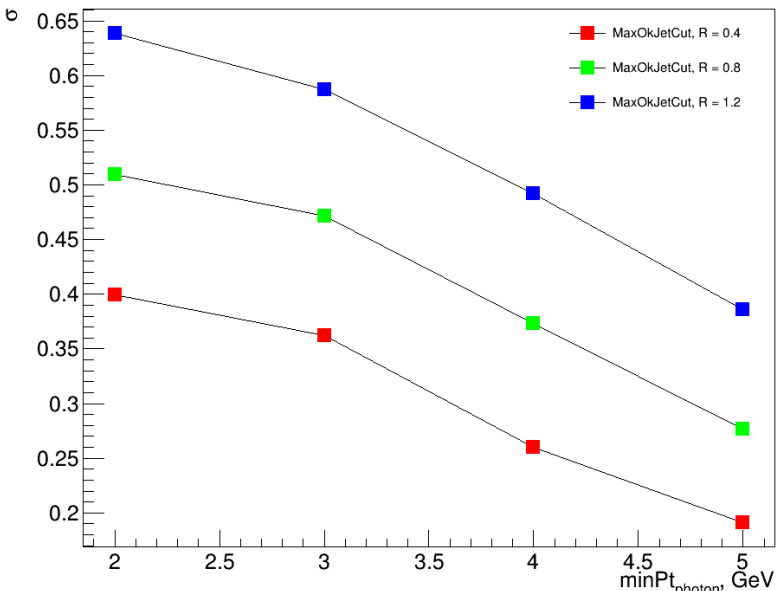
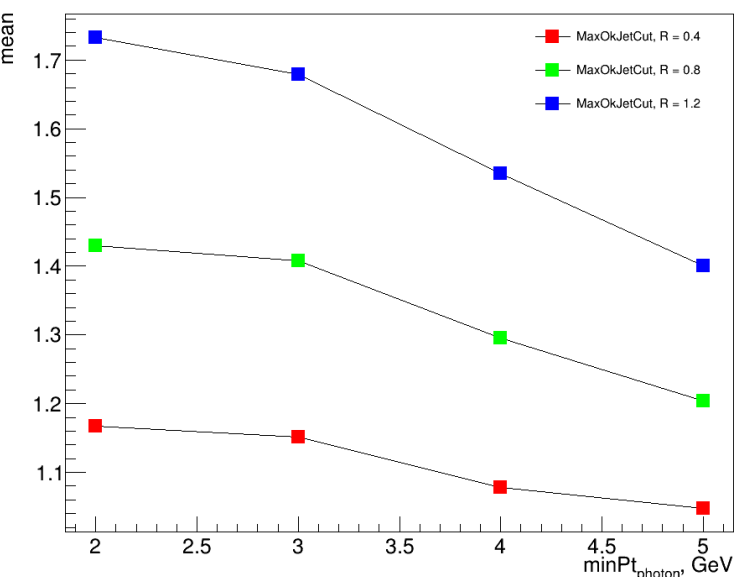
- High p_T jets have good association with initial parton

Clustered jet (φ, η) vs parton (φ, η)

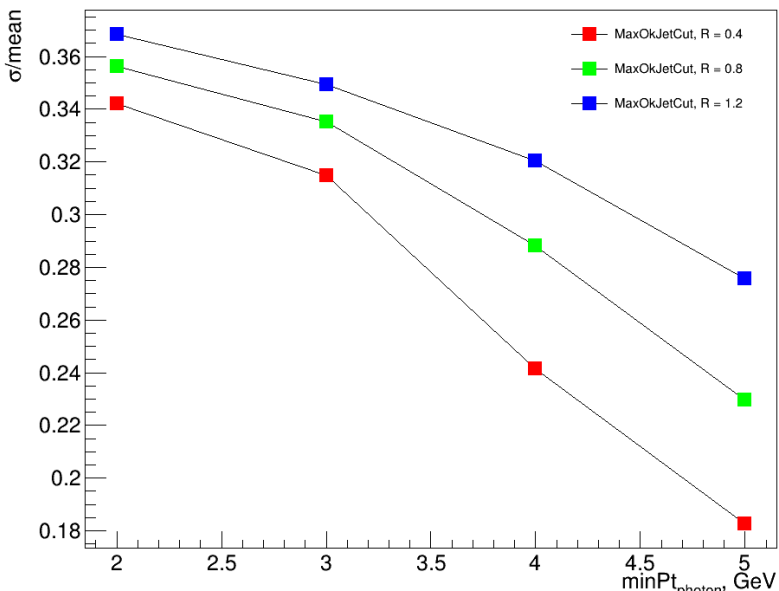


■ Jets and partons moves in the same direction

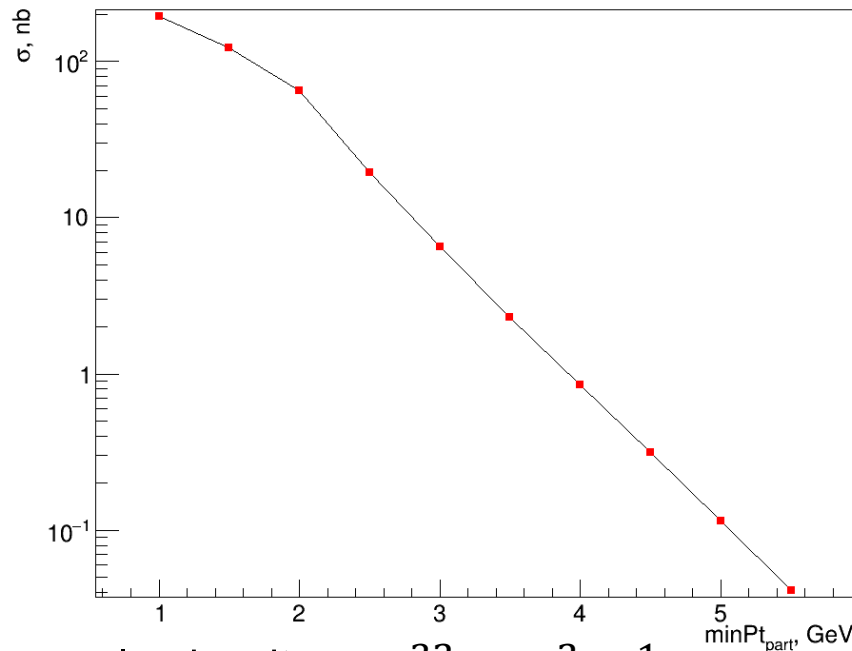
Mean values and σ



■ Increasing radius parameter of clustering algorithm worsen parton-jet association



Process $qg \rightarrow q\gamma$ cross section ($\sqrt{s} = 27$ GeV)



- Expected instantaneous luminosity - $10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
- For 100 days of work integral luminosity $\sim 10^5 \text{ nb}^{-1}$
- We have enough statistics even for high p_T partons
- For partons with $p_T > 3 \text{ GeV}$ we expect $\sim 10^6$ events

Conclusion and plans

- Kinematical properties of hard scattered partons and clustered jets was compared on generator level
- If we use cuts on $p_{T,parton}$ then there are objects which could be associated with initial parton
- Cuts on leading photon p_T and back to back condition between jet and photon together with cut on leading jet p_T select jets which could be associated with initial parton
- Different clustering algorithms find similar jets, but we have to study time of their work
- Increasing radius parameter of clustering algorithm worsen parton-jet association
- We expect enough statistics to make these analysis
- Plans:
 - Analyzing of inclusive jet production
 - Check additional approaches to find clusters of particles
 - Repeat this study with full simulation of detector

Back up

Anti- k_t algorithm

- Jets are clustered with *anti- k_t* algorithm
- Distance between objects in *anti- k_t* algorithm defined as $d_{ij} = \min\left(\frac{1}{k_{ti}^2}, \frac{1}{k_{tj}^2}\right) \frac{\Delta_{ij}^2}{R^2}$,
where $\Delta_{ij}^2 = (y_i - y_j)^2 + (\varphi_i - \varphi_j)^2$
- The functionality of the algorithm can be understood by considering an event with a few hard particles and many soft ones
 - If hard particle 1 has no hard neighbours within a distance $2R$ then we have one perfectly conical jet
 - If another hard particle 2 is present such that $R < \Delta_{12} < 2R$ then we have two jets with some overlapping parts
 - If distance between particles 1 and 2 $\Delta_{12} < R$ then both formed one jet

Magnetic field effects

- Magnetic field change trajectories of charged particles and affect on jet reconstruction:
 - Jets becomes wider along phi angle
 - Some low p_T particles spin and go to endcaps

- How can we imitate magnetic field impact:

- We assume that magnetic field is uniform and equal to 1T in whole detector
- We take particle coordinates and calculate their change after some small dt as:

$$dv_x = c(p_x/p)dt$$

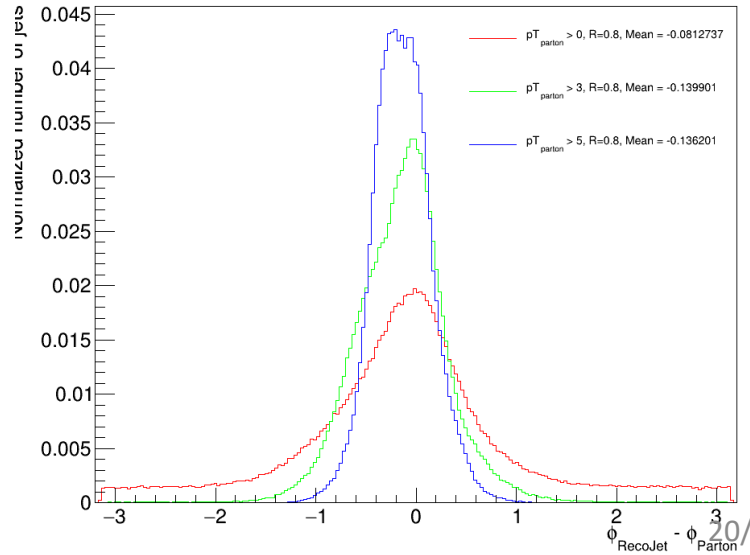
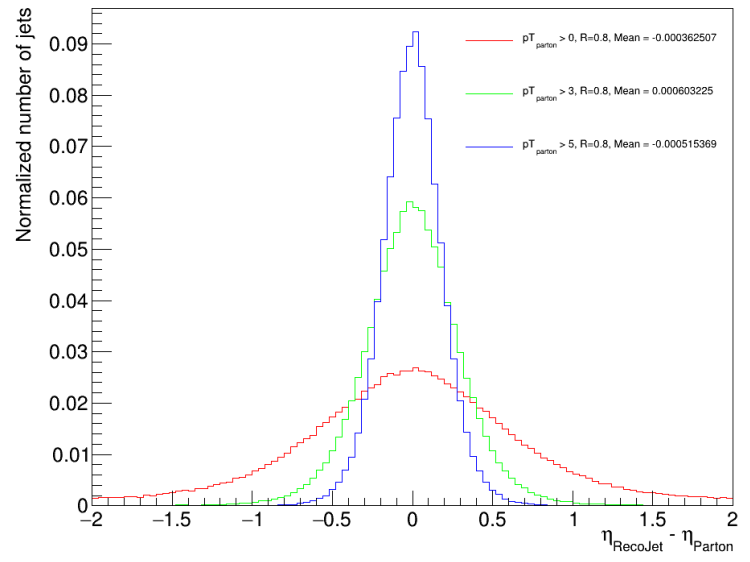
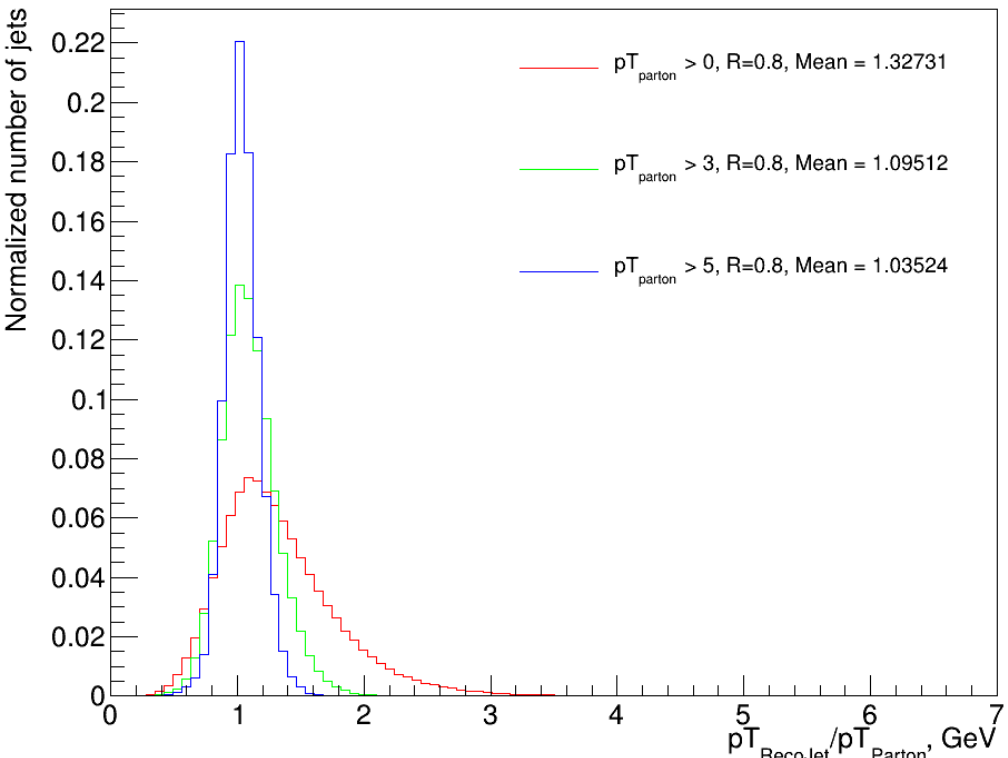
- And we can calculate change of p_x and p_y :

$$dp_x = \frac{c^2 q}{E} (p_y B_z) dt$$

$$dp_y = \frac{c^2 q}{E} (-p_x B_z) dt$$

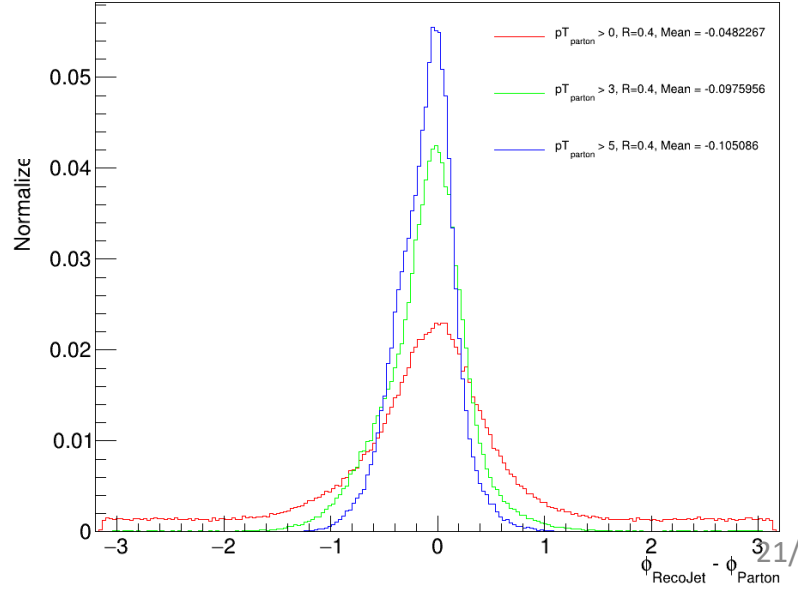
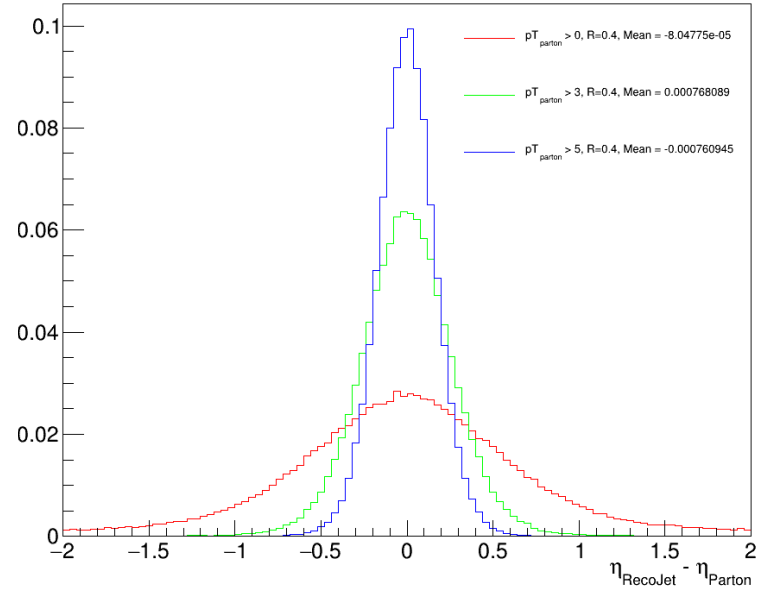
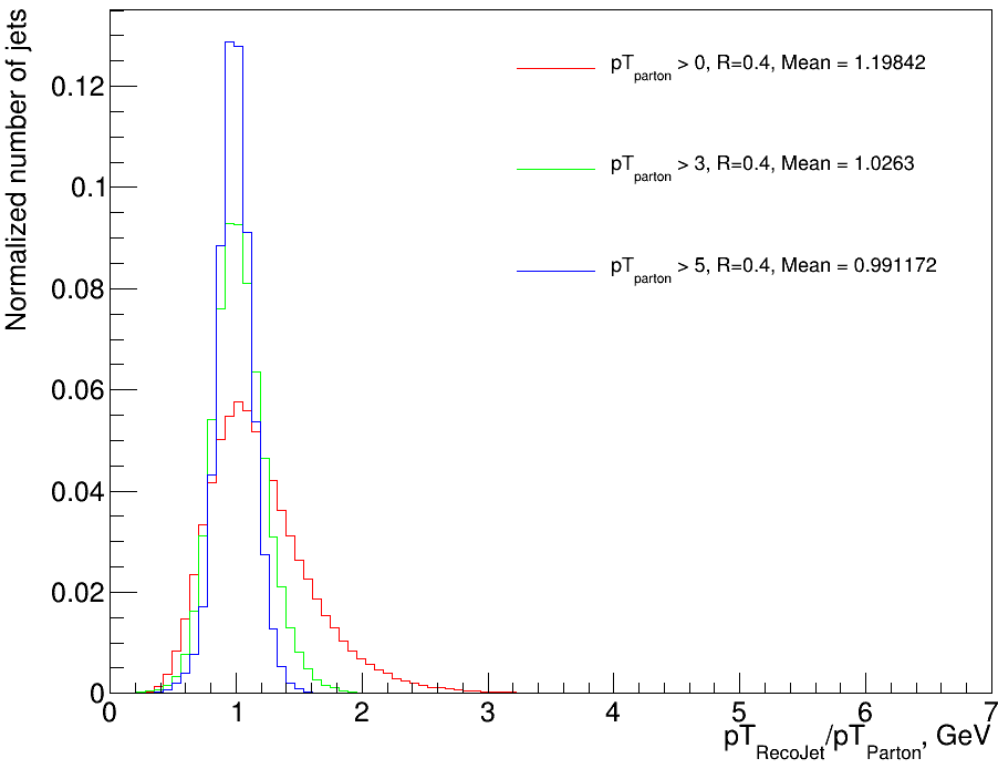
- We continue this iterations until $v_{xy} < 1080mm$, i.e. particle reach ECal
- In the end we recalculate momentum of particle assuming that it moves directly from their vertex to place where it reach ECal

Clustered jet vs parton (R=0.8, with magnetic field)



- Phi resolution asymmetric because events have more positive charged particles
- Number of jets with magnetic field ~3 time less that without magnetic field for same statistics
- Fraction of jets with charged leading particle strongly depends on $p_{T, \text{parton}}$
 - $p_{T, \text{parton}} > 0 \text{ GeV} \sim 30\%$
 - $p_{T, \text{parton}} > 5 \text{ GeV} \sim 60\%$

Clustered jet vs parton (R=0.4, with magnetic field)



Clustered jet vs parton (R=0.6, with magnetic field)

