Parton discrimination using jets with ALICE at the LHC

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for the ALICE Collaboration

5th Workshop on High p_T Physics at LHC
ICN UNAM, Mexico City
28th September 2010

Outline

- Physics motivation
- ALICE and jet reconstruction
- Quark/Gluon discrimination methods
    - Second moment of transverse structure
    - Track counting method
- Jet fragmentation into charged particles

Parton discrimination

Objective: Distinguish quark and gluon jets

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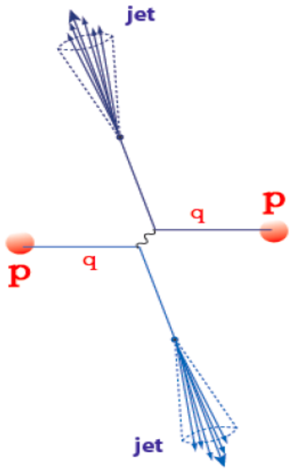
pp
- Study of jet properties
- Parton fragmentation in vacuum
- Test of pQCD
- Study biases in jet finding



Parton discrimination

Objective: Distinguish quark and gluon jets

pp

- Study of jet properties
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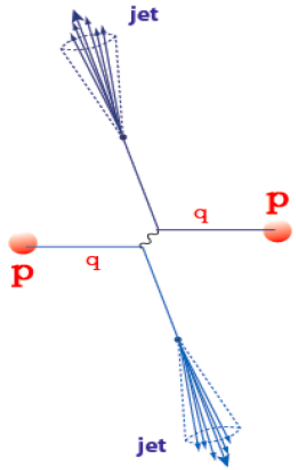
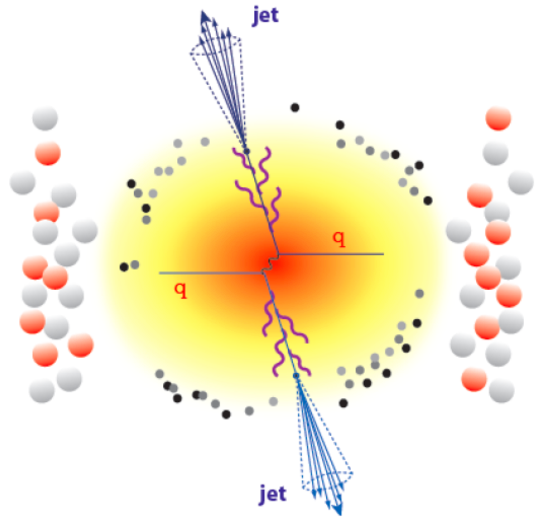
- Test of pQCD
- Study biases in jet finding

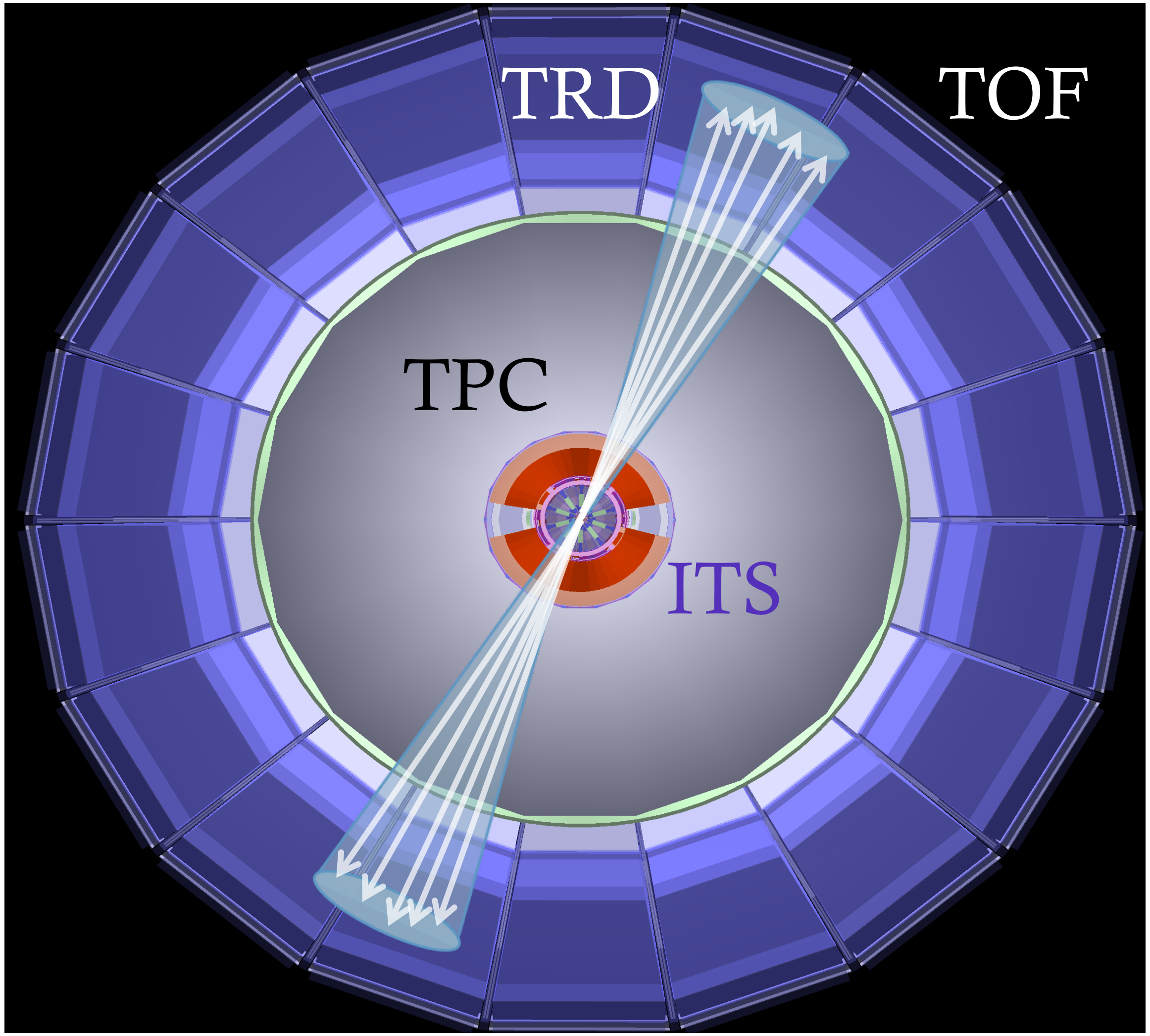
A+A

- In medium fragmentation
- Modification on fragmentation
- Response of QGP to different partons





ALICE and jet reconstruction



ALICE

- Dedicated experiment to study heavy ion collisions at LHC
- Well suited to study jet composition due to tracking and PID capabilities.

JETS

- Charged particle jets with the central barrel detectors $|\eta| < 0.9$

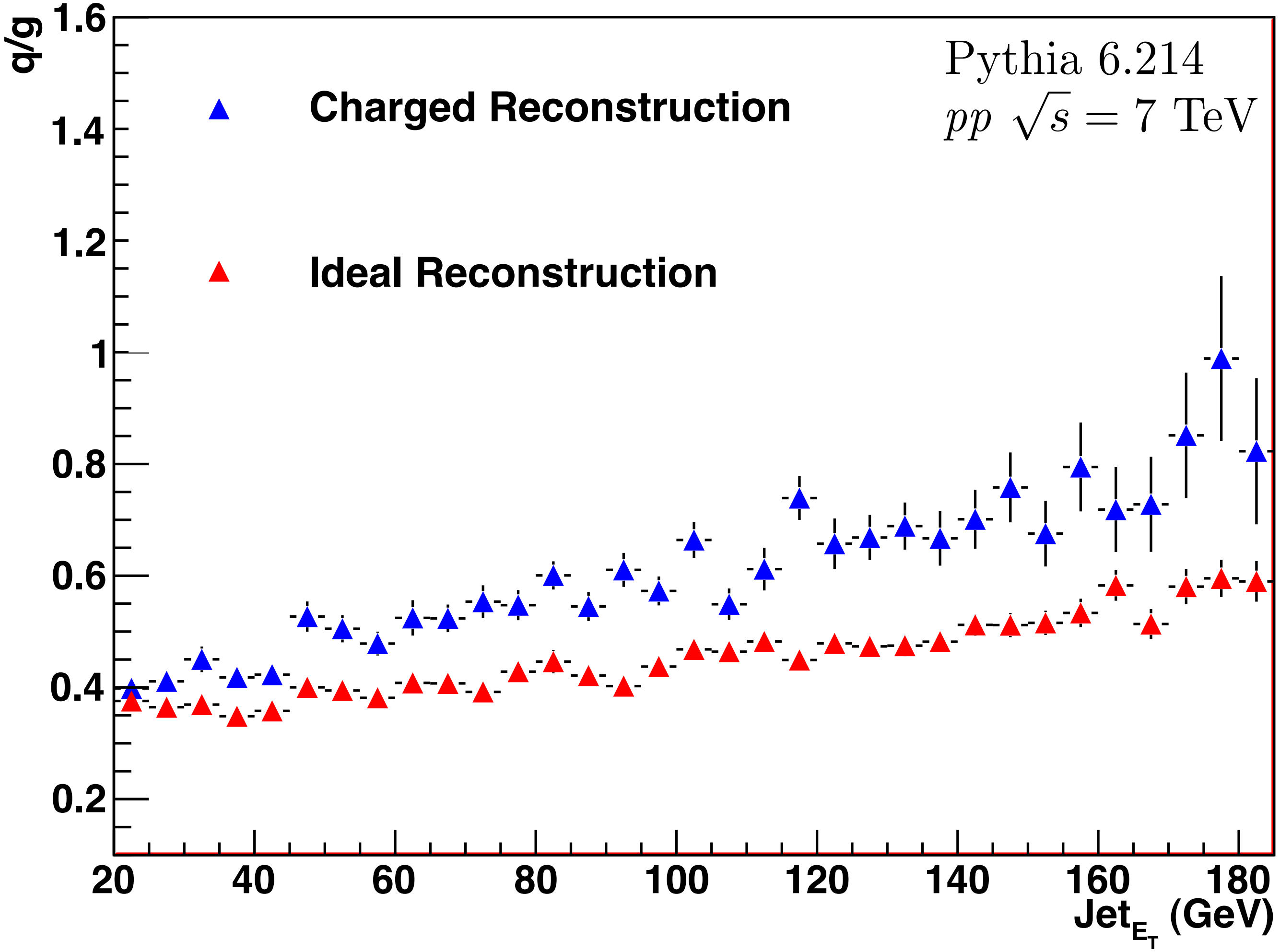
In the future ALICE will use tracking + EMCal for jet reconstruction

Data Sample and Jet Finder

Data Sample	
Pythia Jet Events with full ALICE simulation	
Proton-Proton at 7 TeV	PYTHIA 6.214
PDF : CTEQ4L	

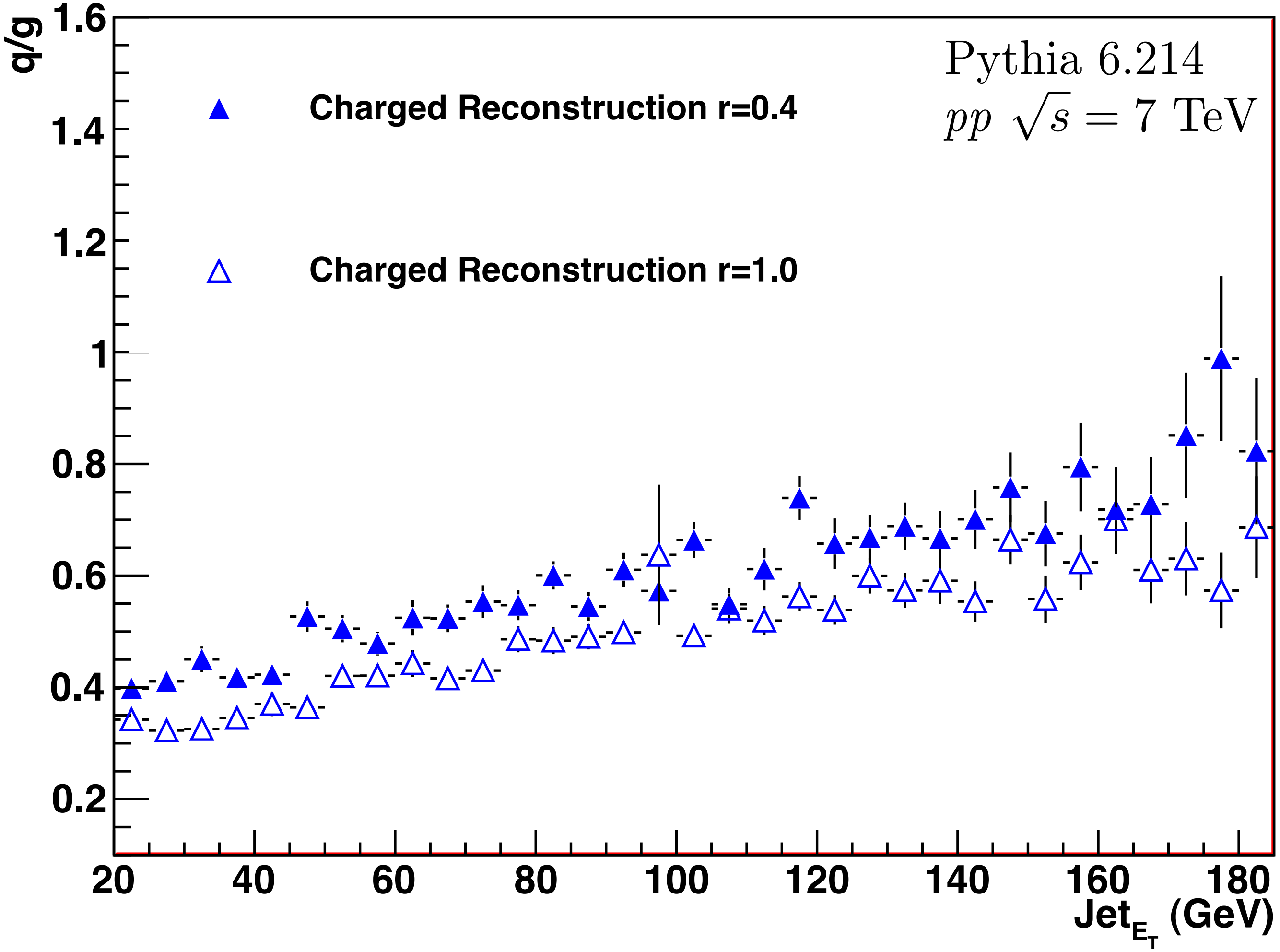
UA1 Jet Finder
Radius: 0.4
E_TSeed: 4 GeV
MinJetE_T: 5 GeV
Only on charged particles

Detection bias on charged reconstruction



-Gluon jets are lost due to the charged jet reconstruction

Detection bias on charged reconstruction



-Bias towards finding quark jets due to small cone radius

Quark/gluon discrimination methods

- Second moment of transverse structure
- Track Counting Method

Second moment of transverse structure

CMS NOTE: PAS QCD-08-002

$$\langle \delta R_c^2 \rangle = \langle \delta \phi_c^2 \rangle + \langle \delta \eta_c^2 \rangle \quad \ldots \text{ (1)}$$

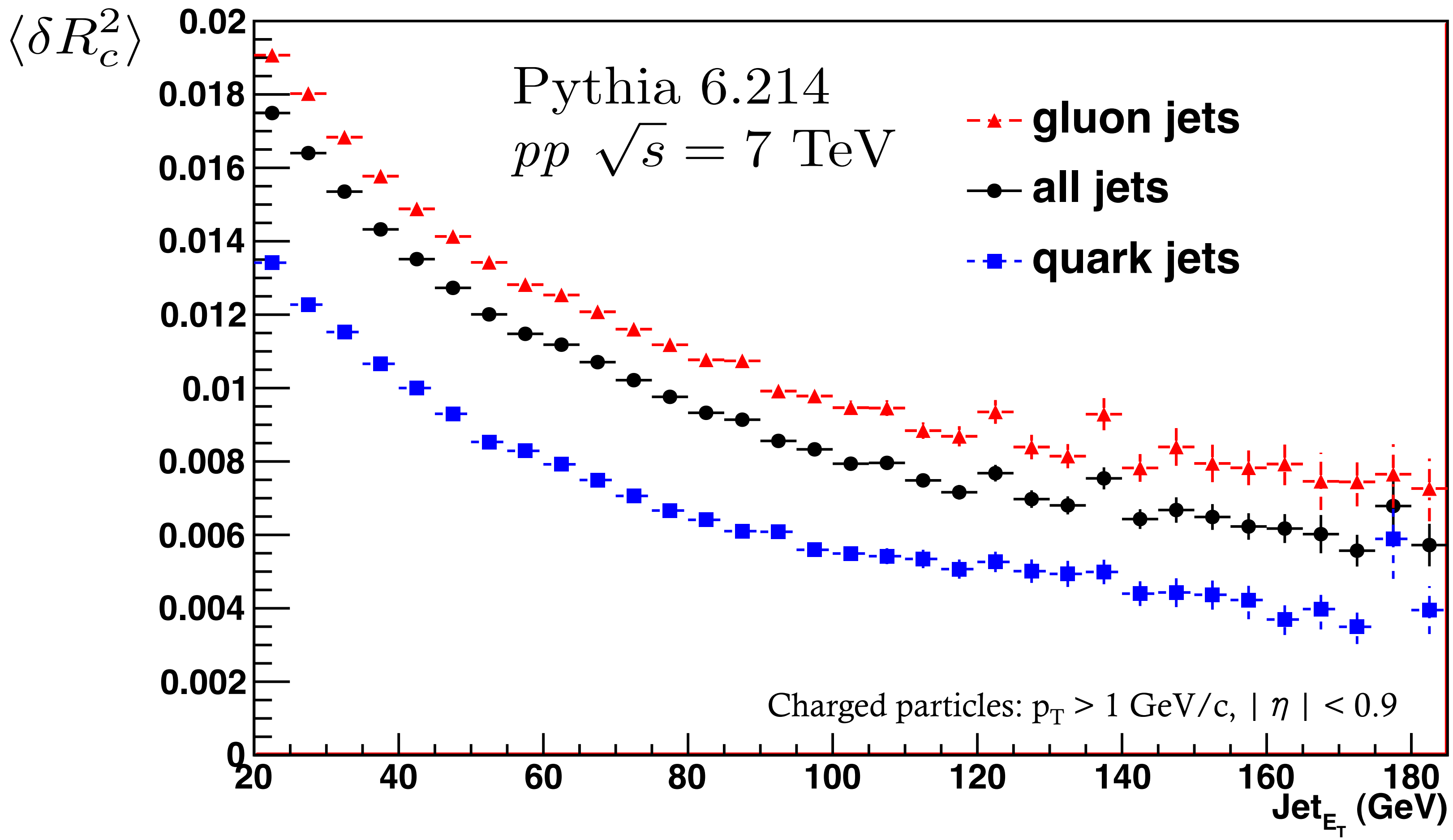
$$\langle \delta \alpha_c^2 \rangle = \langle \delta \alpha_j^2 \rangle - \langle \delta \alpha_j \rangle^2 \quad \ldots \text{ (2)} \qquad \alpha = \phi, \eta$$

$$\langle \delta \alpha_j^n \rangle = \frac{\Sigma_i (\alpha_j - \alpha_i)^n \times p_T^i}{\Sigma_i p_T^i} \quad \ldots \text{ (3)}$$

$j \longrightarrow \phi, \eta$ of the jet

$i \longrightarrow$ Charged tracks inside the jet

Second moment of transverse structure



Mean values of $\langle \delta R_c^2 \rangle$ are larger for gluon jets

Track counting

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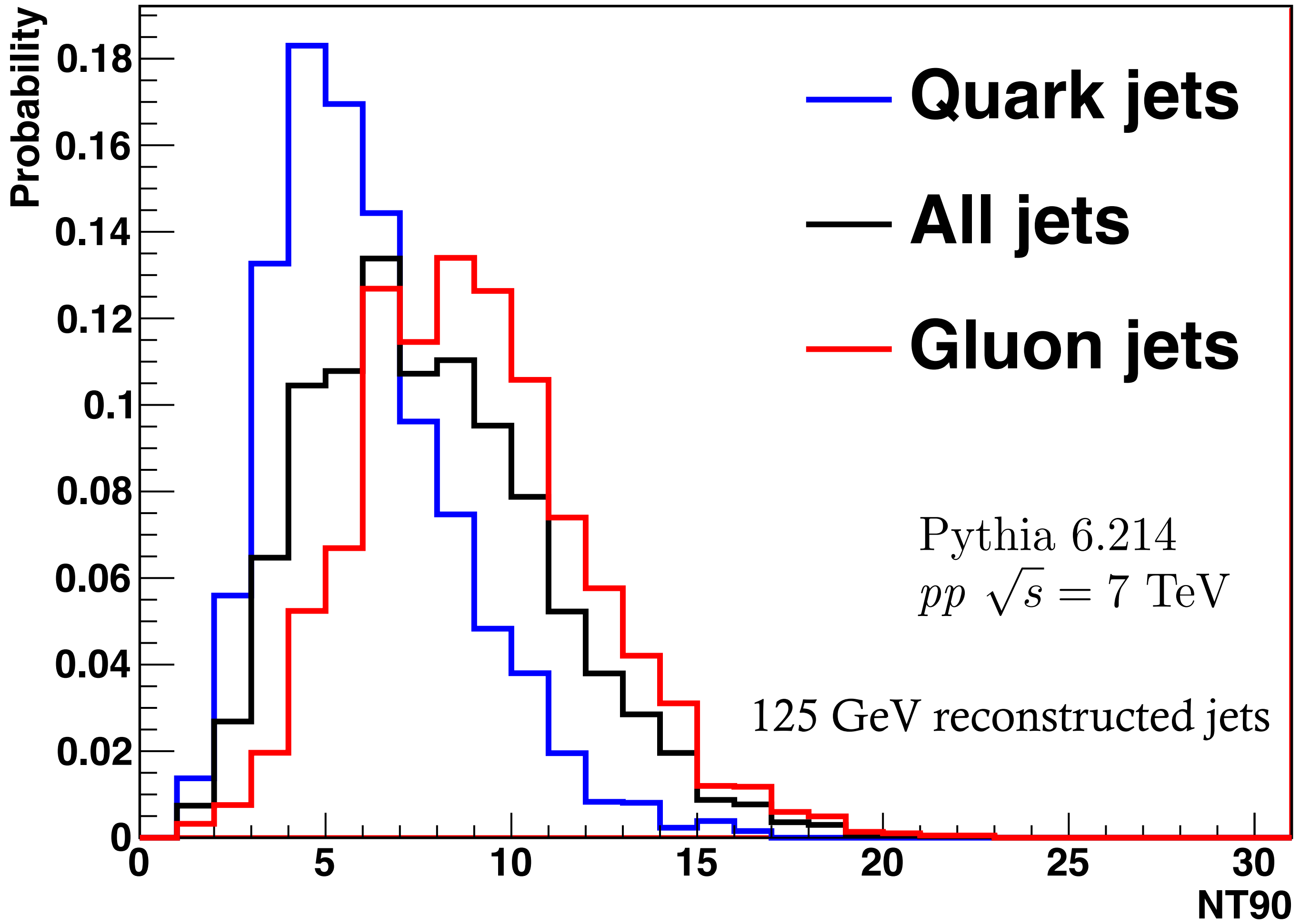


- Order the tracks that belong to the jet in decreasing p_T
- Add the ordered tracks until 90% of the energy of the jet is recovered
- NT90 is the minimum number of tracks to recover 90% of the jet energy

Comparison of methods

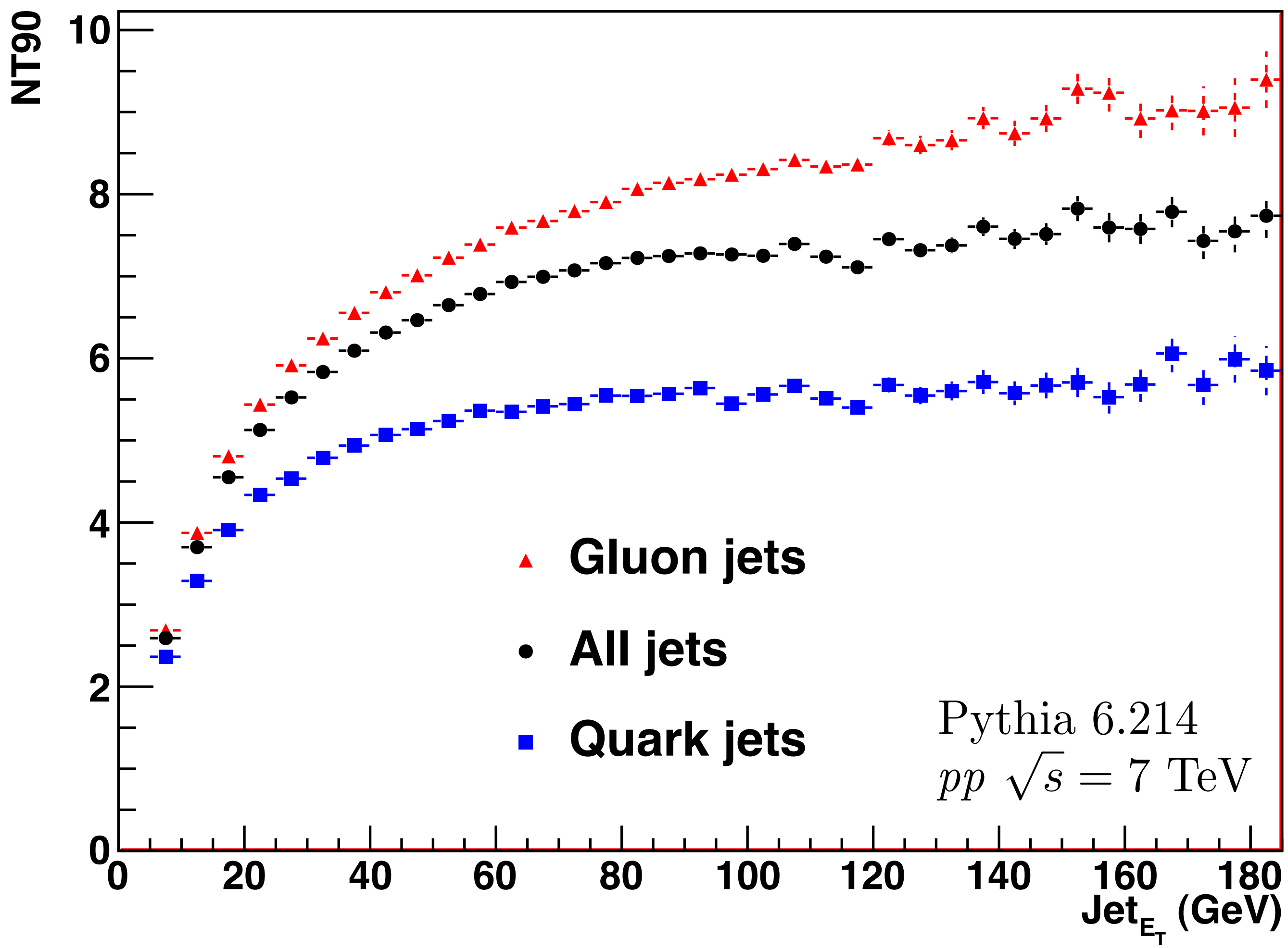
Results for
125 GeV Quark Jets

Method	Purity	Efficiency
$\langle \delta R_c^2 \rangle$	61 %	38 %
NT90	64 %	69 %

-The NT90 method is more efficient to discriminate quark from gluon jets, reaching the same value of purity.

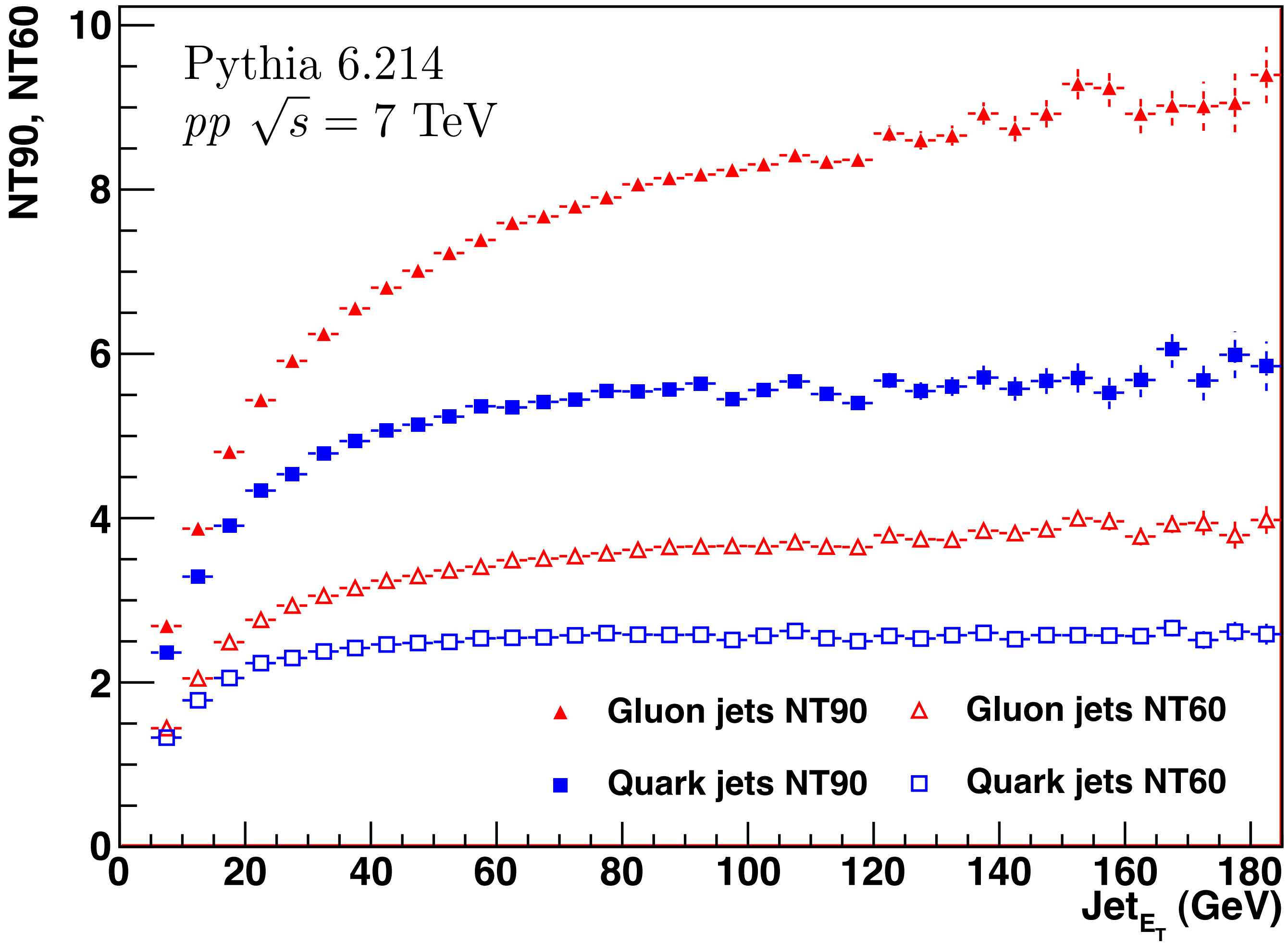
-Attempts to combine both methods were not successful:
NT90 and $\langle \delta R_c^2 \rangle$ were highly correlated (no increase in purity achieved).

Track counting



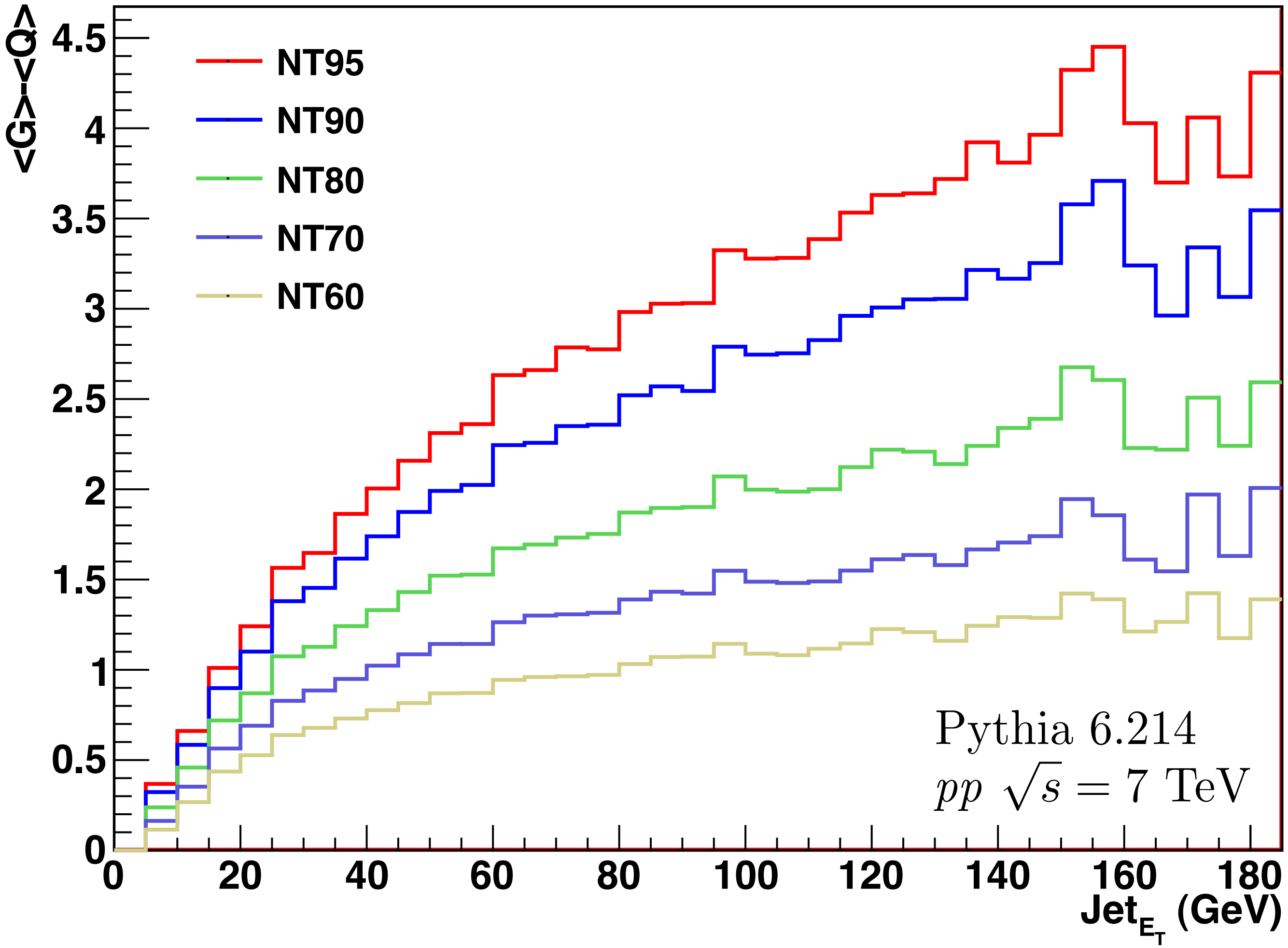
Mean values of NT90 are larger for gluon jets in all the Jet E_T range.

Track counting



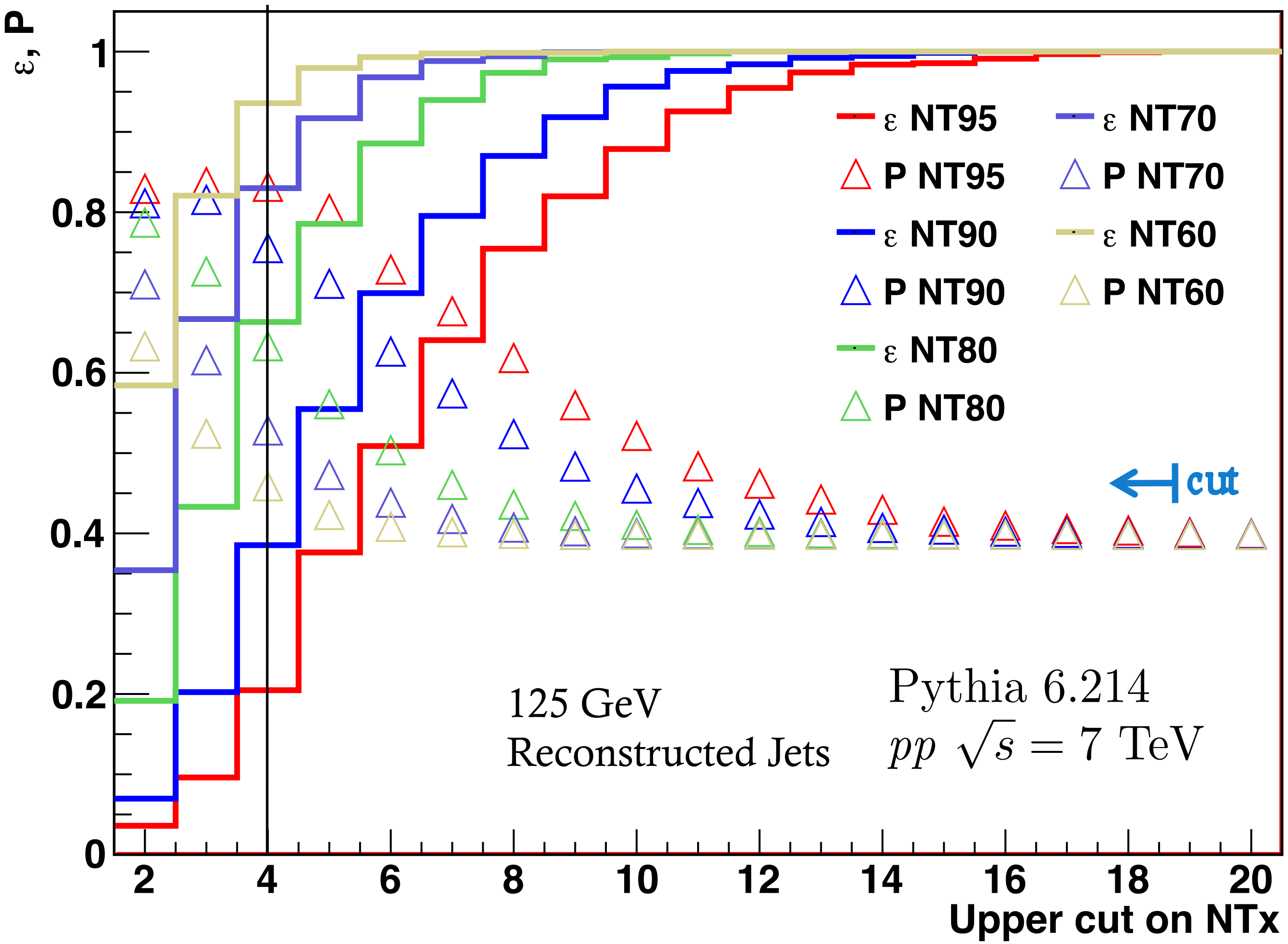
Larger difference of mean values for NT90 than for NT60.

Track counting



Increase on the difference of mean values as the recovered energy increases.

Track counting



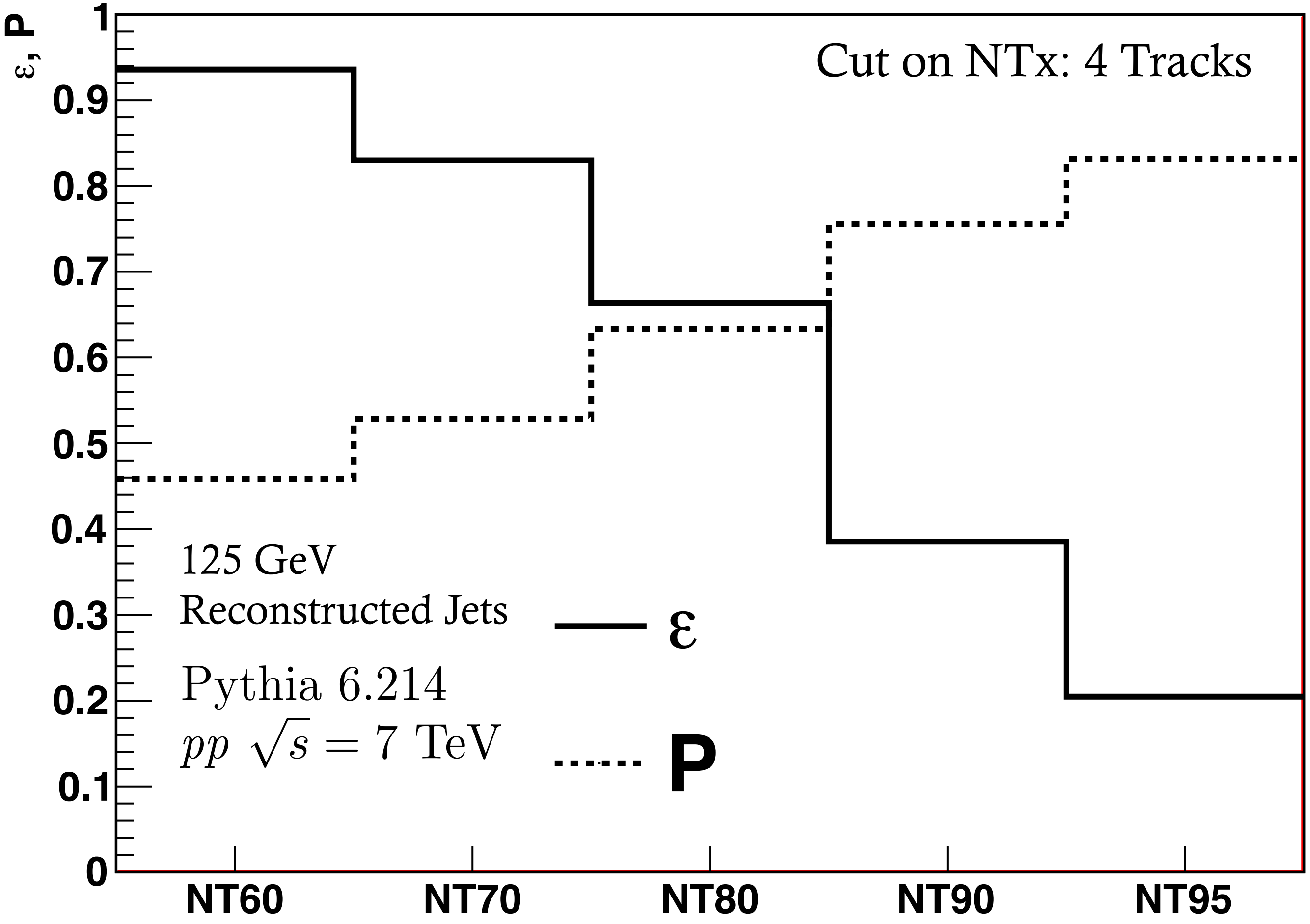
Efficiency and purity for quark jet selection.

$$\varepsilon_q = \frac{\Sigma_i Jet^i_q|_{cut}}{\Sigma_i Jet^i_q}$$

$$P_q = \frac{\Sigma_i Jet^i_q|_{cut}}{\Sigma_i Jet^i_{q+g}|_{cut}}$$

NTx: NT60, NT70, NT80, NT90 & NT95

Track counting



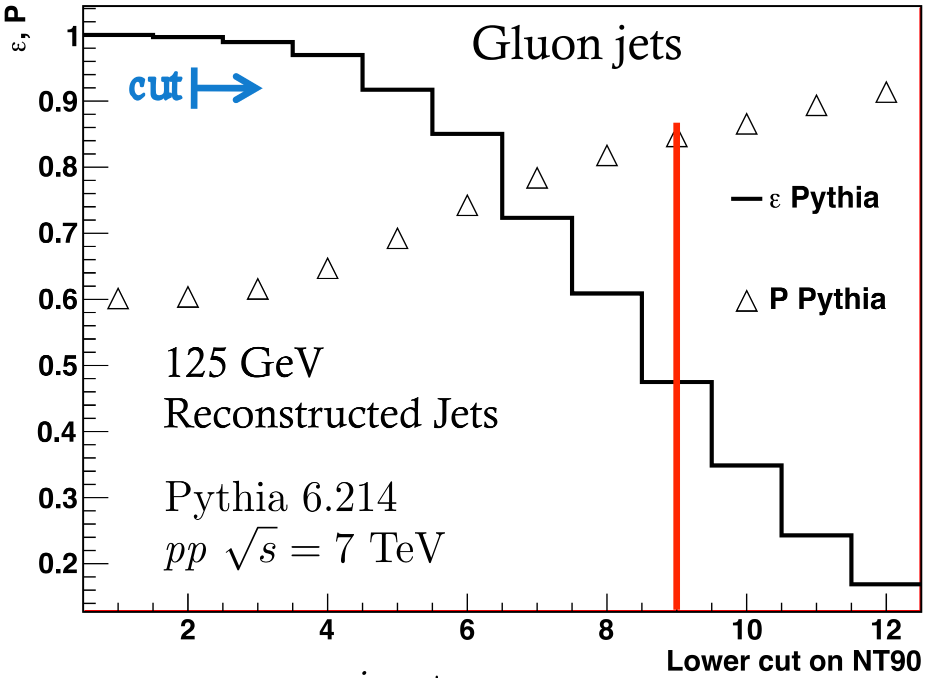
Efficiency and purity for quark jet selection.

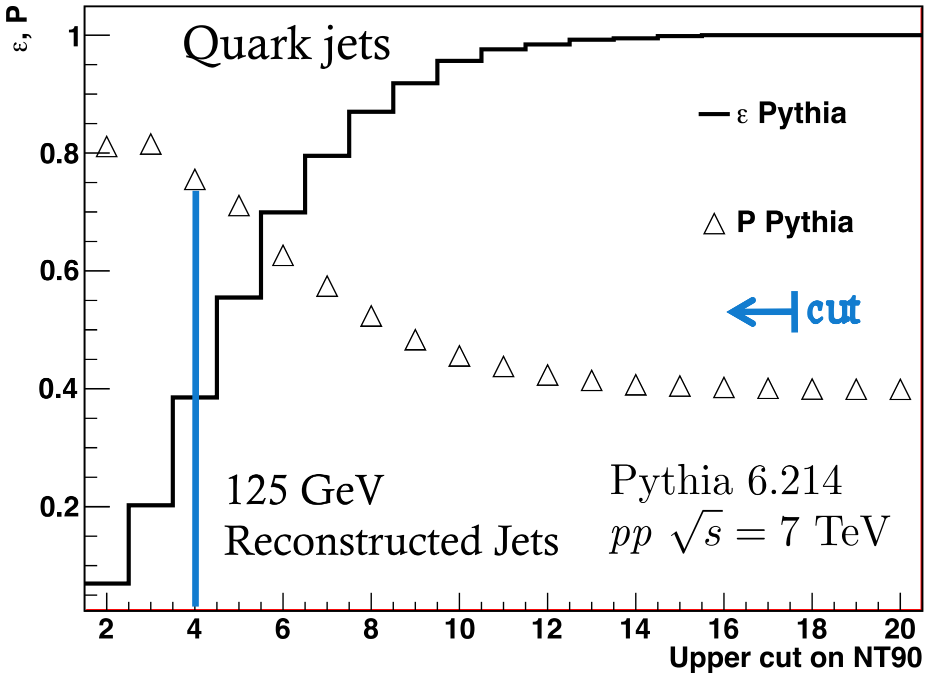
$$\varepsilon_q = \frac{\Sigma_i Jet_q^i|_{cut}}{\Sigma_i Jet_q^i}$$

$$P_q = \frac{\Sigma_i Jet_q^i|_{cut}}{\Sigma_i Jet_{q+g}^i|_{cut}}$$

NT90 is a compromise of efficiency of the method and sample purity.

Track counting, ideal case (MC)



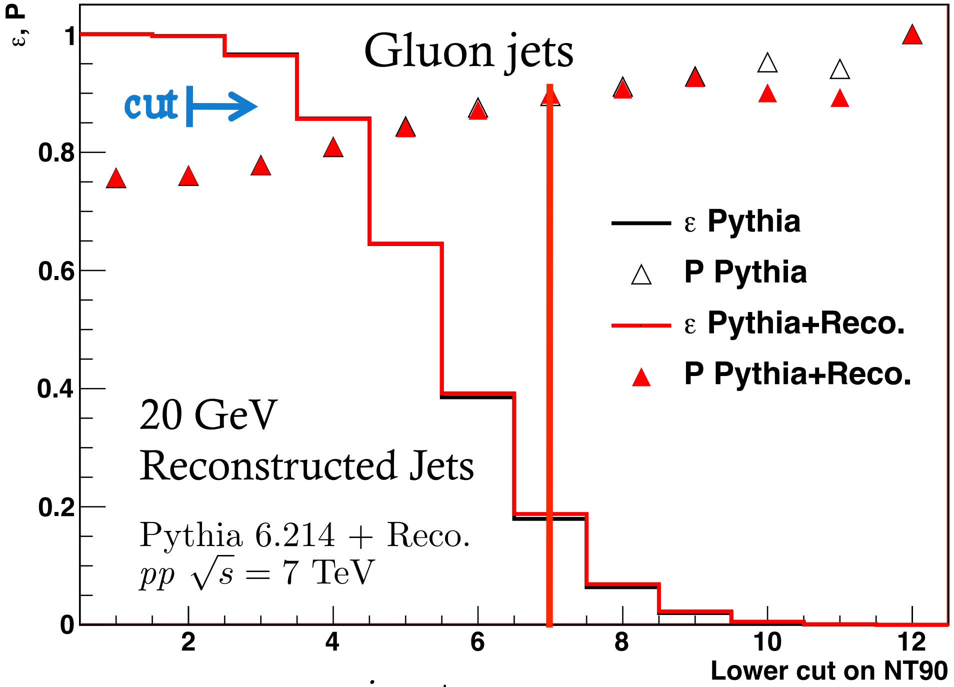


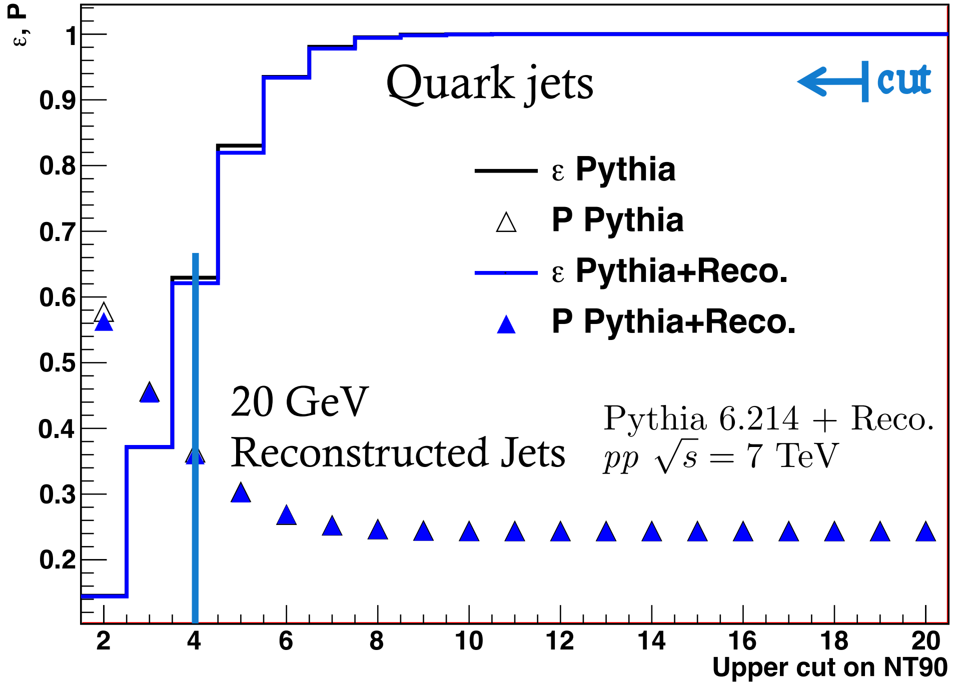
$$\varepsilon_{q/g} = \frac{\Sigma_i Jet^i_{q/g}|_{cut}}{\Sigma_i Jet^i_{q/g}}$$

$$P_{q/g} = \frac{\Sigma_i Jet^i_{q/g}|_{cut}}{\Sigma_i Jet^i_{q+g}|_{cut}}$$

Parton	Cut	Purity (enhance)	Efficiency
Gluon	9	84 % (24%)	48 %
Quark	4	76 % (36%)	38 %

Track counting, comparison





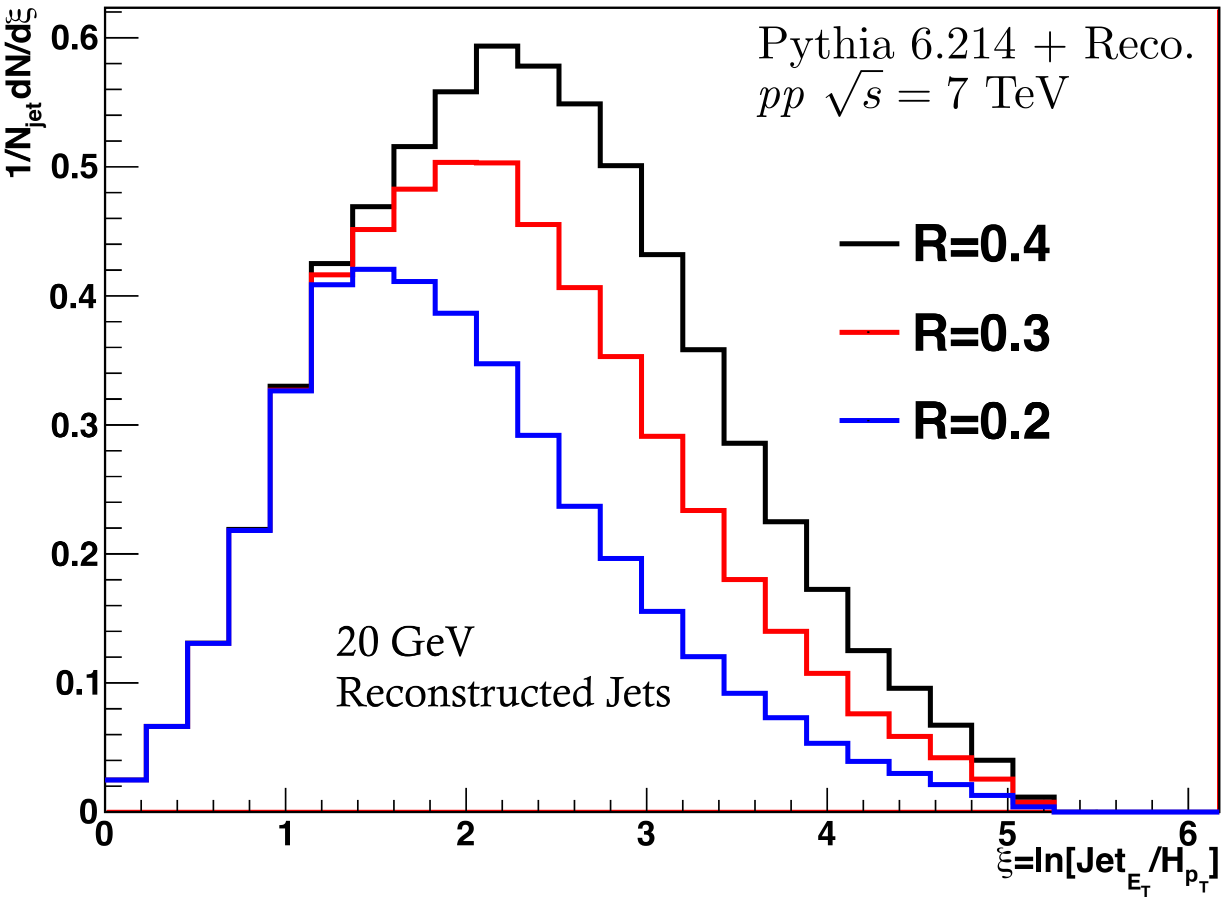
$$\varepsilon_{q/g} = \frac{\Sigma_i Jet^i_{q/g}|_{cut}}{\Sigma_i Jet^i_{q/g}}$$

$$P_{q/g} = \frac{\Sigma_i Jet^i_{q/g}|_{cut}}{\Sigma_i Jet^i_{q+g}|_{cut}}$$

Parton	Cut	Purity (enhance)	Efficiency
Gluon	7	90 % (14%)	18 %
Quark	4	36 % (12%)	63 %

Charged particle fragmentation

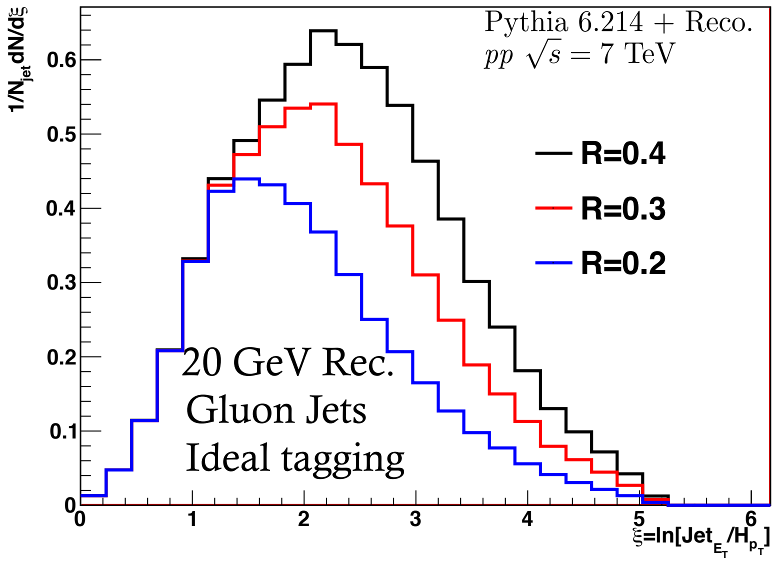
- Measure the charged fragmentation in p-p collisions.
- Baseline for the Pb-Pb fragmentation
- Expected hardening of the spectra with decreasing sub-radius

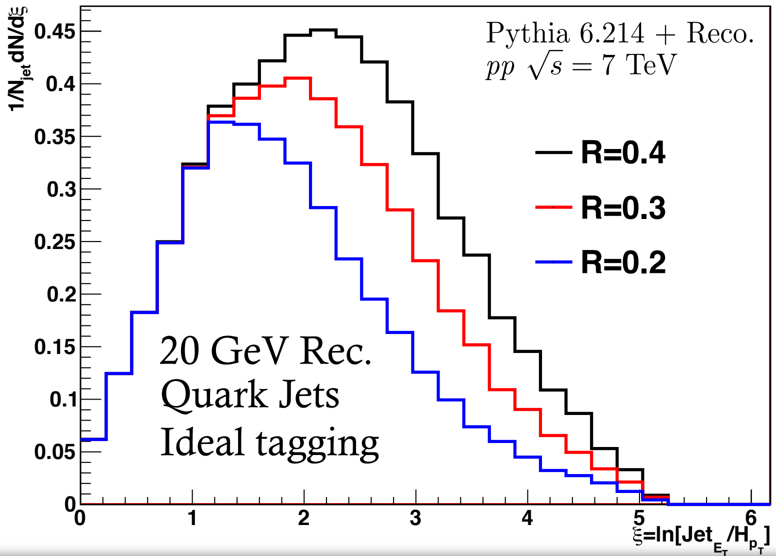


Sapeta, Wiedemann, Eur. Phys. J. C 55 (2008) 293-302

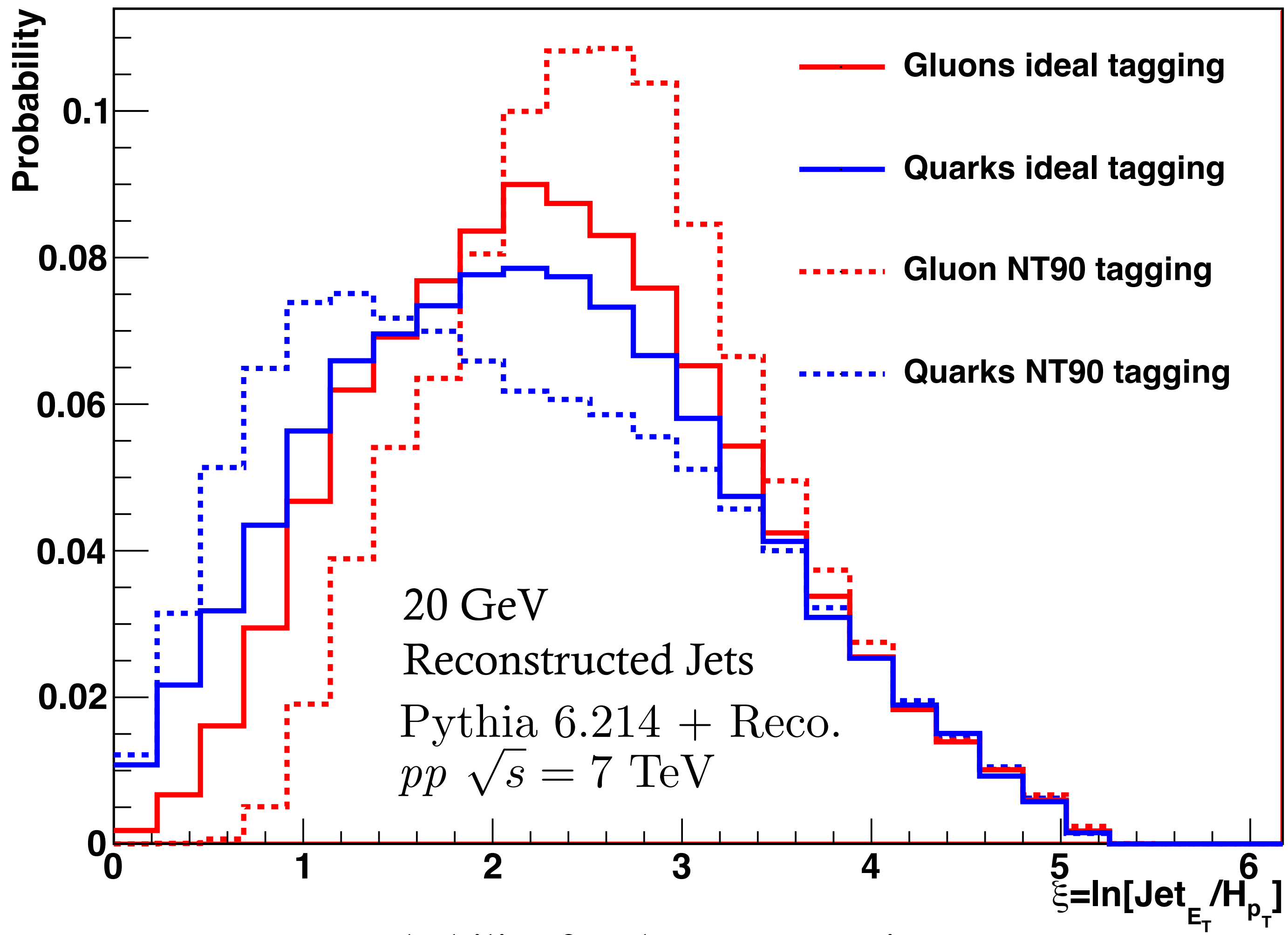
Quark and gluon fragmentation

- Use the quark/gluon tagging to study the differences in charged particle fragmentation.
- Softer fragmentation for gluon jets
- Compare jet charged composition as a function of jet sub-radius with data.





Charged particle fragmentation



N.B. Probability for shape comparison

Cuts:

- Gluon Jets:

NT90 $\geq$ 7 Tracks

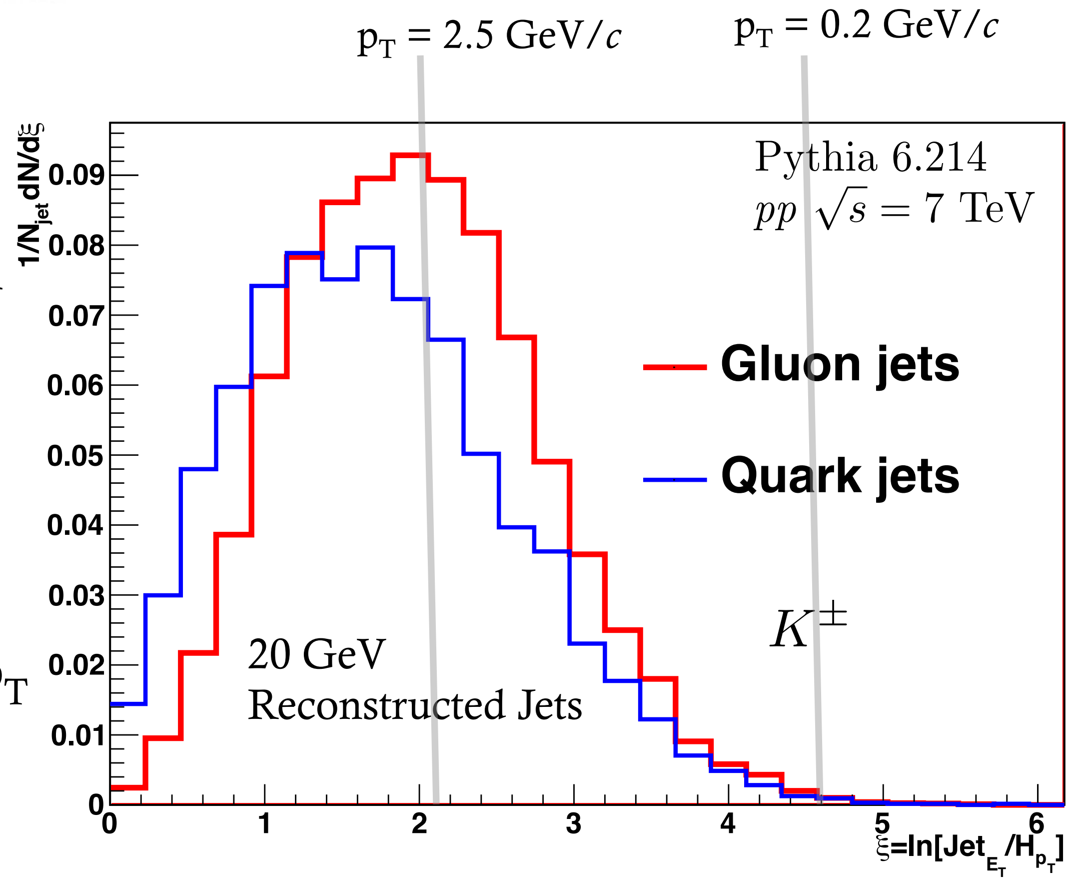
- Quark Jets:

NT90 $\leq$ 4 Tracks

Bias towards soft/hard fragmentation respectively

Outlook

- Energy dependent cuts.
- Jet fragmentation as a function of inner radii.
- Use of different jet finder.
- Identified particle fragmentation: $K^{\pm}$ low p_T; K^0



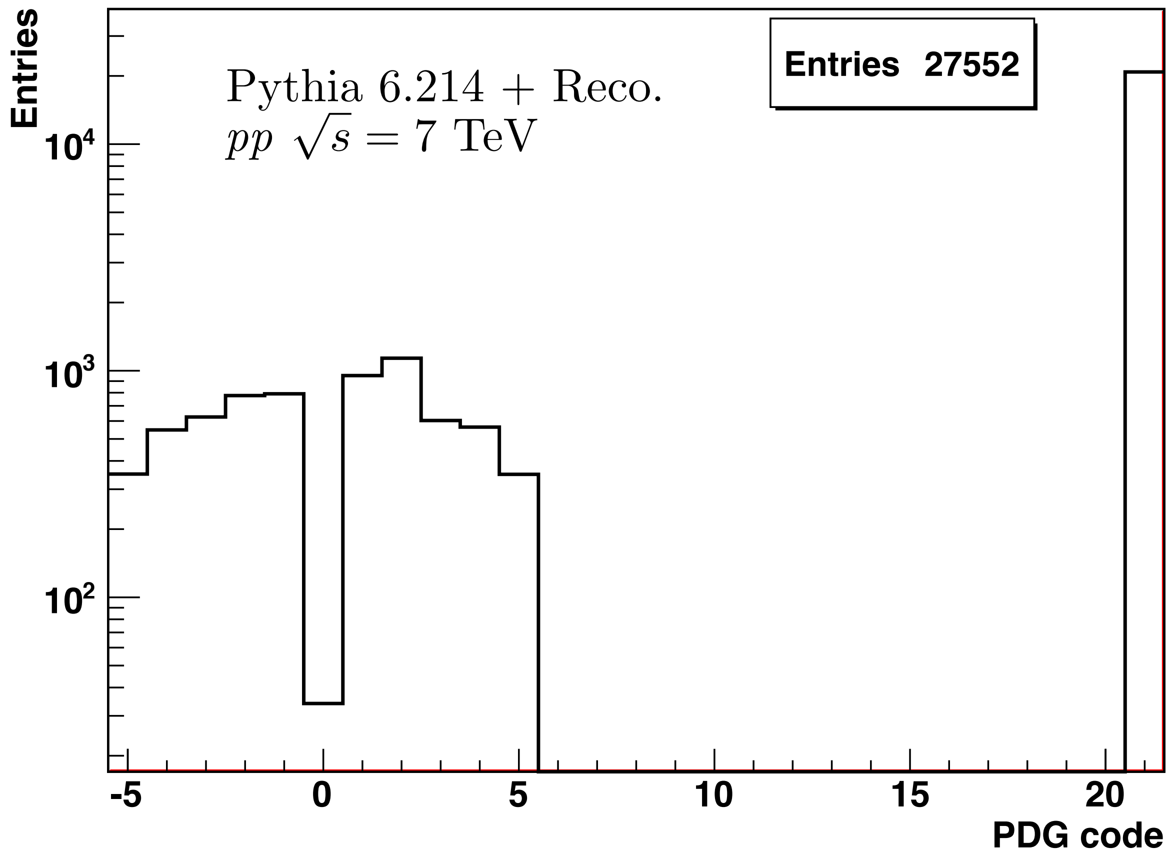
Conclusion

- Using the excellent tracking capabilities of ALICE it is possible to use tagging variables to discriminate jets produced from quarks or gluons.

- With its PID capabilities, ALICE can make significant contributions to the study of jet chemistry.

Back up

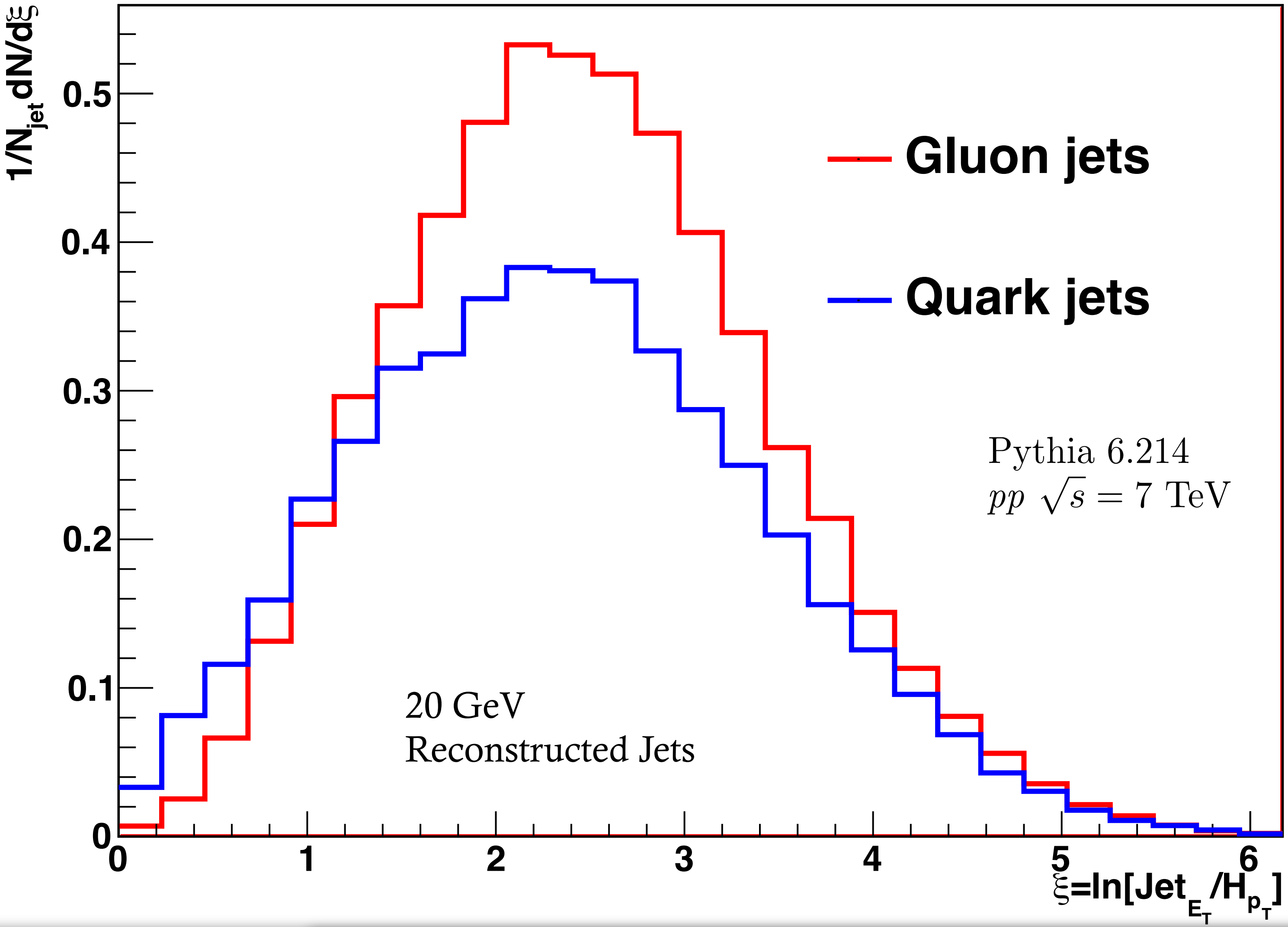
Jet flavour (definition)



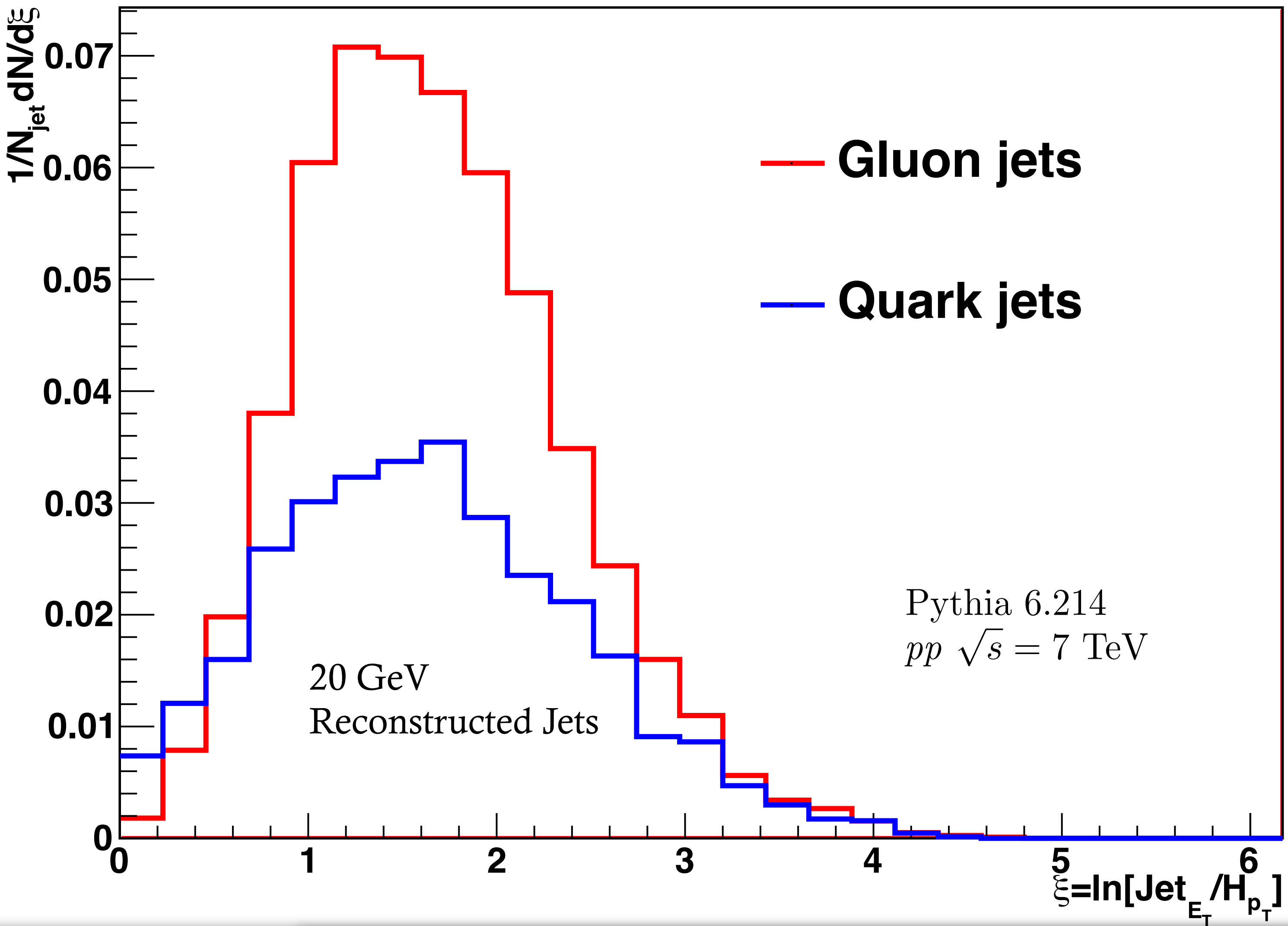
The flavour is that of the most energetic parton within $\Delta R = 0.3$ of the jet axis.

Parton	PDG code
d	1
u	2
s	3
c	4
b	5
gluon	21

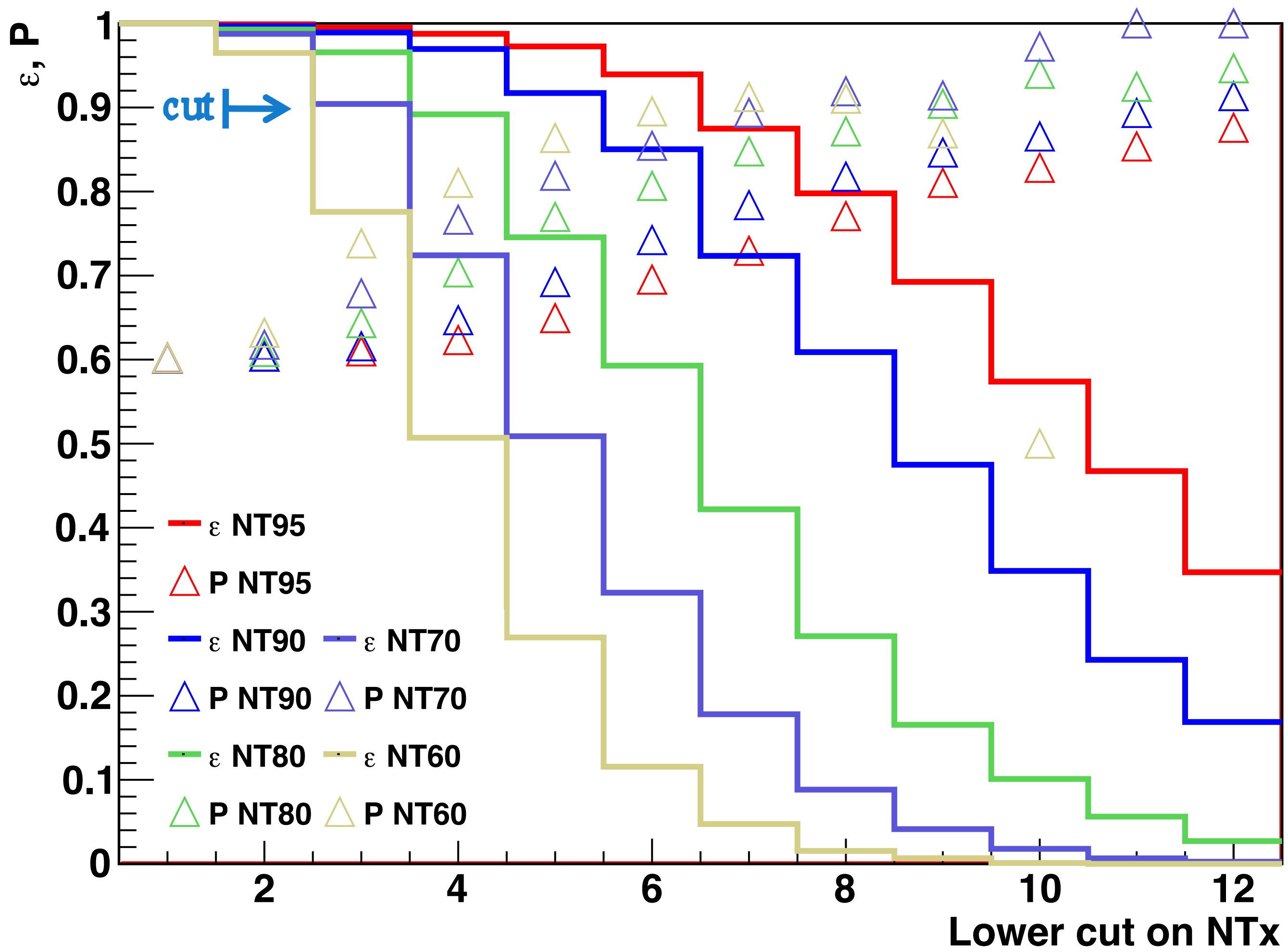
Charged pion fragmentation



Charged proton fragmentation



Gluon NT



Pythia 6.214
$pp\ \sqrt{s} = 7$ TeV

125 GeV
Reconstructed Jets