Experimental treatment of Quark and Gluon Jets

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Quark/Gluon jet differences
Motivation to study them separately

Separation method
Possibility to use multi-jet and gamma-jet events

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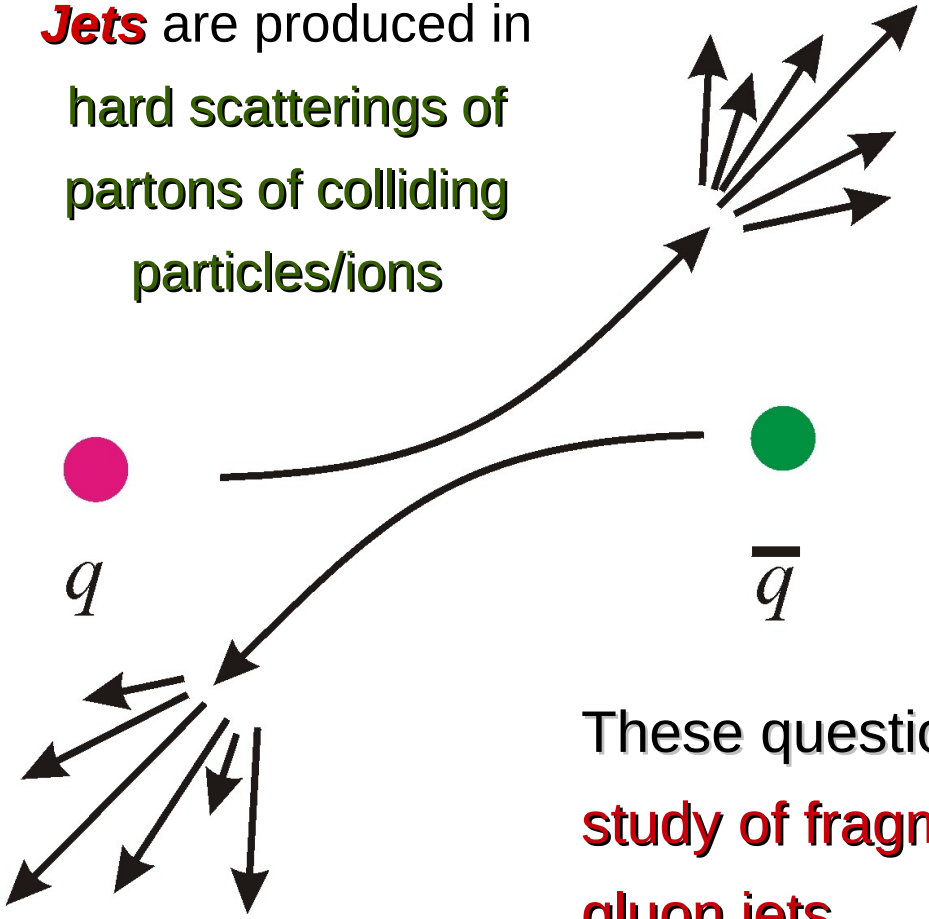
Introduction

Jets are produced in **hard scatterings of partons of colliding particles/ions**



Emerging from the very early stages of collisions they are ideal to study

Early stages of collisions
Hadronisation processes
Particle production

These questions can be addressed through the **study of fragmentation properties of quark and gluon jets**

Quark and Gluon Jets

Quark and gluon jet carry different colour factors

$$\frac{C_A}{C_F} = \frac{9}{4} = 2{,}25 \; (Q \to \infty)$$

The colour factors are proportional to the **probability a parton radiates soft gluon**

Gluons branch more easily and are expected to form

Higher multiplicity jets

Broader jets

Jets with softer fragmentation function

Quark and Gluon Jets

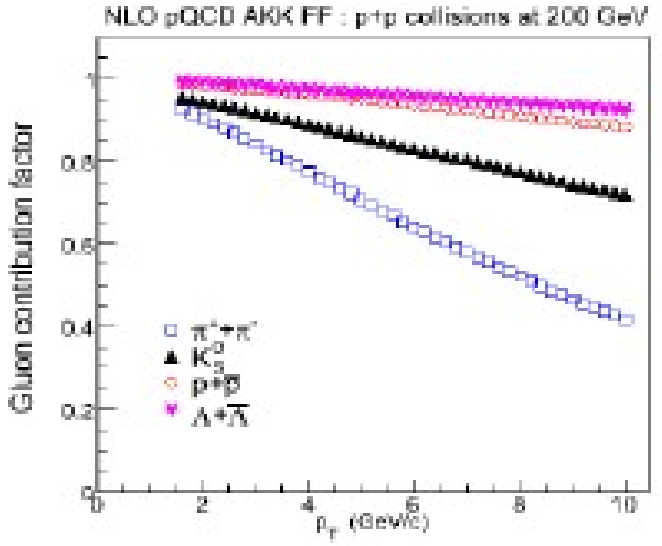
Particle production differences:

Gluons

Baryon production

Quarks

Meson production



S. Albino, B.A. Kniehl, and G. Kramer - NPB 725 (2005) 181

Higher multiplicity jets

Broader jets

Jets with softer fragmentation function

Variables connected to jet-properties study

- **Jet-shape, charged multiplicity**
- **Fragmentation functions,...**

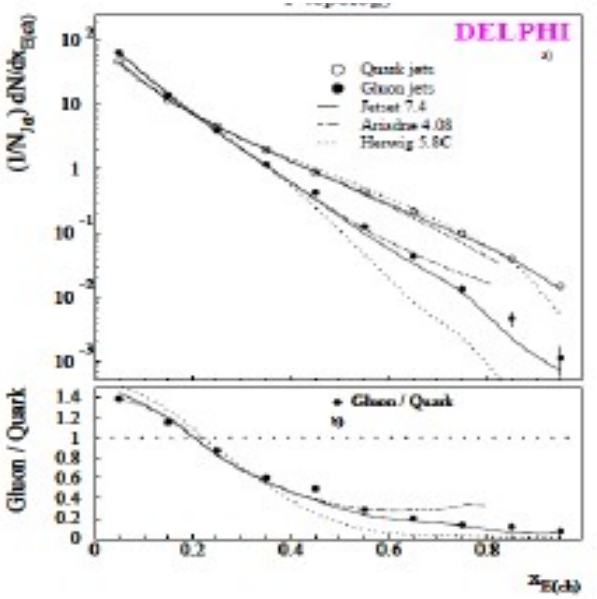
The differences in the frag. properties of q/g jets must naturally be represented in the experimentally studied variables

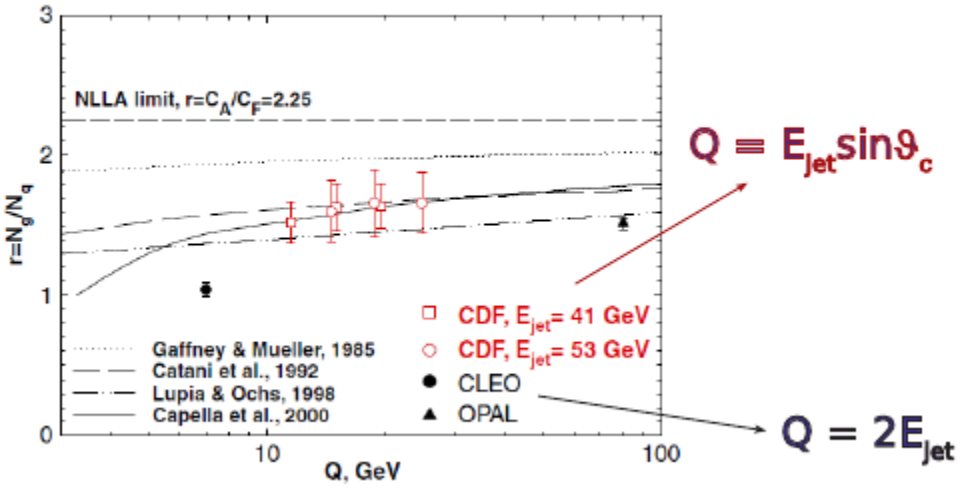
- **identified hadron spectra, multiplicity, R_{AA},...**

MC models

- First studies looking at properties of jets were conducted in e^+e^- (LEP)
- **Tevatron – pp @ 2 TeV**

arXiv:hep-ex/0110084



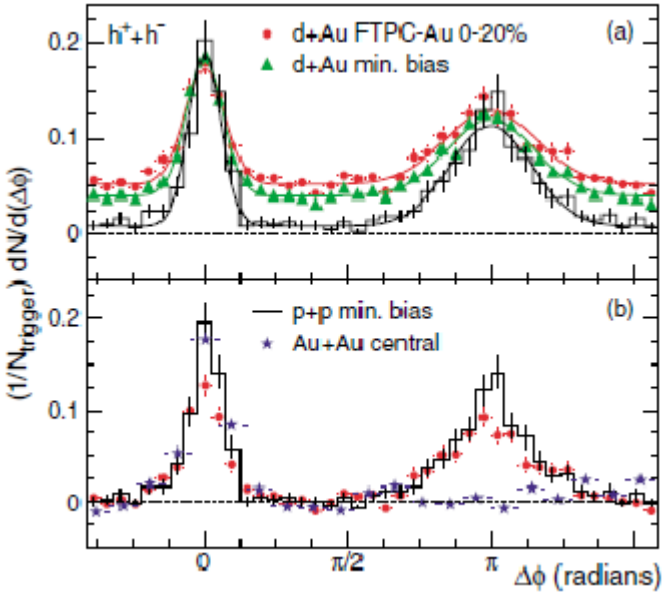


Qualitatively, differences were observed, however, asymptotic limit was not

RHIC

RHIC – colliding HI; possibility to investigate matter formed in such collisions through modification of jet

Many interesting and unexpected observations



J. Adams *et al.*, Phys. Rev. Lett. 91 (2003) 072304

Away side jet suppression

⇒ Dramatic softening of jet fragmentation through rapid energy loss while traversing the medium – soft gluon radiation. Particle spectra are sensitive to such behaviour

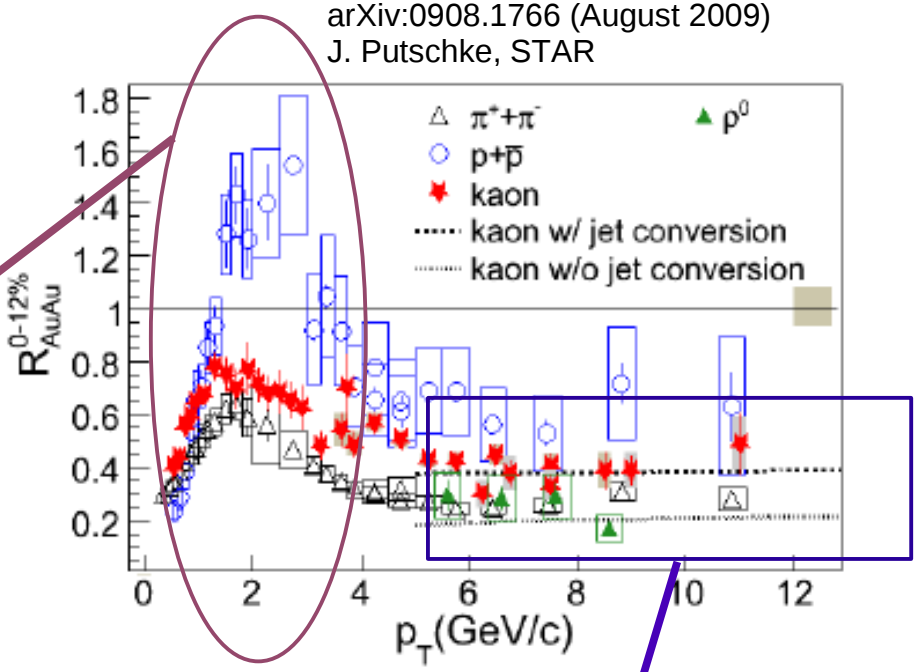
JET INTERACTION WITH MEDIUM

mid p_T hadron yield enhanced

⇒Coalescence of hard partons from jets with soft partons from medium

V. Greco, C.M. Ko, P. Levai, PRL90 (2003) 202302.

arXiv:0908.1766 (August 2009)
J. Putschke, STAR

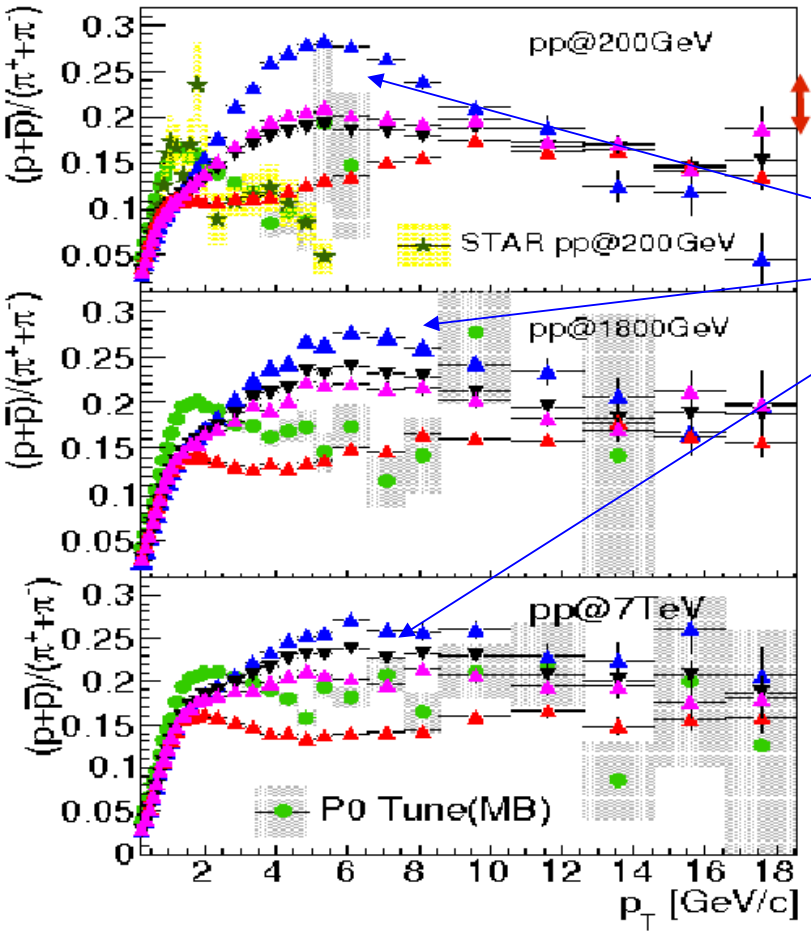


COLOR CHARGE EFFECT OF PARTON ENERGY LOSS

The observed ordering of R_{AA} of identified hadrons is consistent with predictions from calculations including jet flavor conversion in the hot dense medium

Wei Liu, Che Ming Ko, Ben-Wei Zhang
Int.J.Mod.Phys.E16:1930-1936,2007.

SP, arXiv:1009.0868v1 [hep-ex]



The gluon contribution to the ratios changes to lower values with energy (0.3 - 0.25).

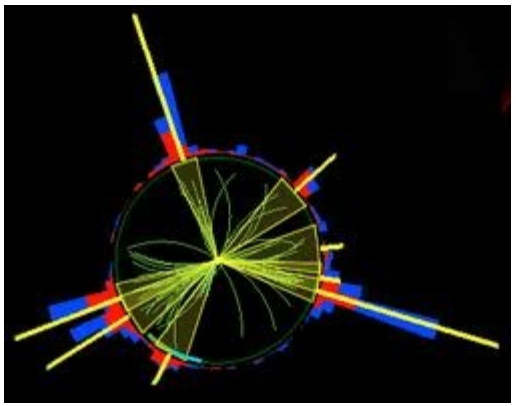
Ratio from all prod.channels on the other hand at ~ TeV energies stays the same (~ 0.25).

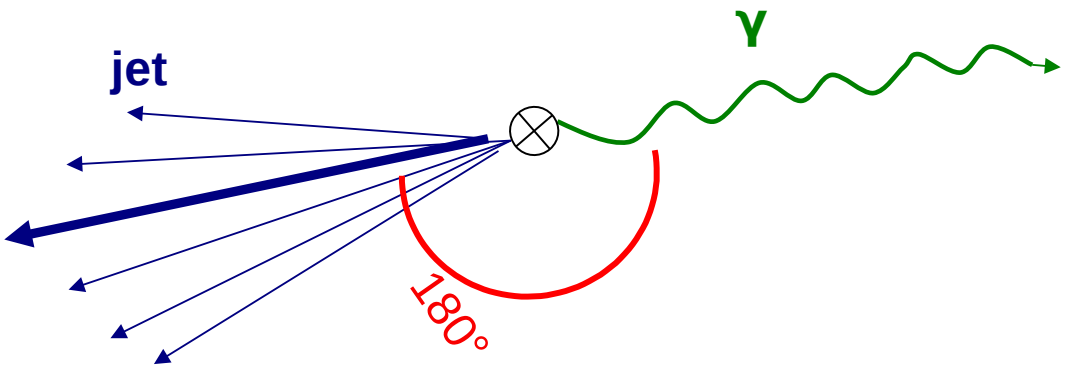
! Important to look at separate prod.channels for tuning purposes as well.

? PYTHIA tunes parameters may lead to underestimation of proton production in the gluon channel when looking at the full event

How to ID the different partons?

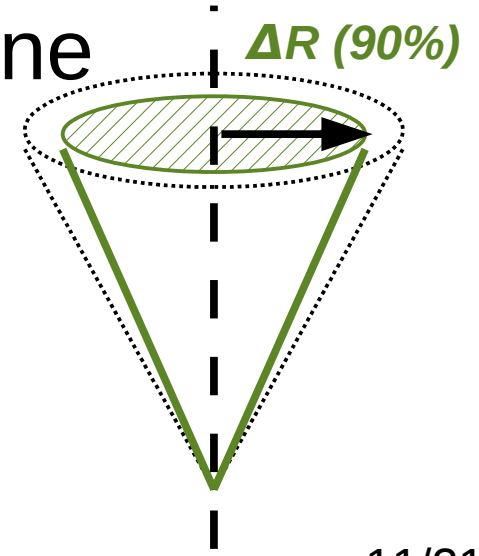
- Use their properties
- Separate “clean” production channels for the production of Q/G
  - G: Multi-jet events
  - Q: gama-jet



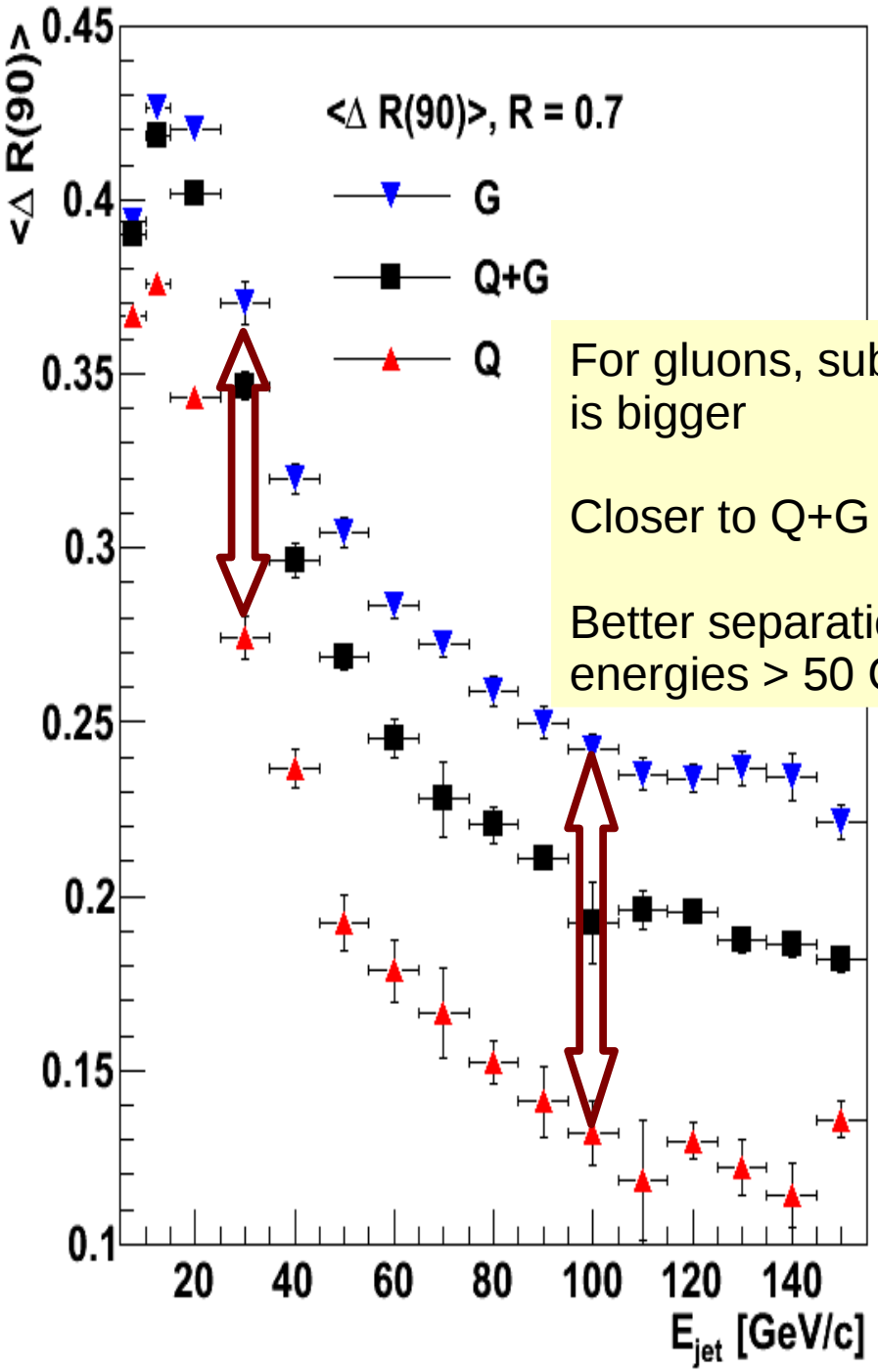


What we did

- Pythia 6, Perugia-0, pp@7TeV
- ***QQ, GG, QG, γ-jets*** channels, each 1M events
- anti-kT algorithm, R = {0.4, 0.7}
- |η| < 0.5, at least 3 charged particles
- Variables: **ΔR(90%)**; size of sub-cone containing 90% of jet's energy



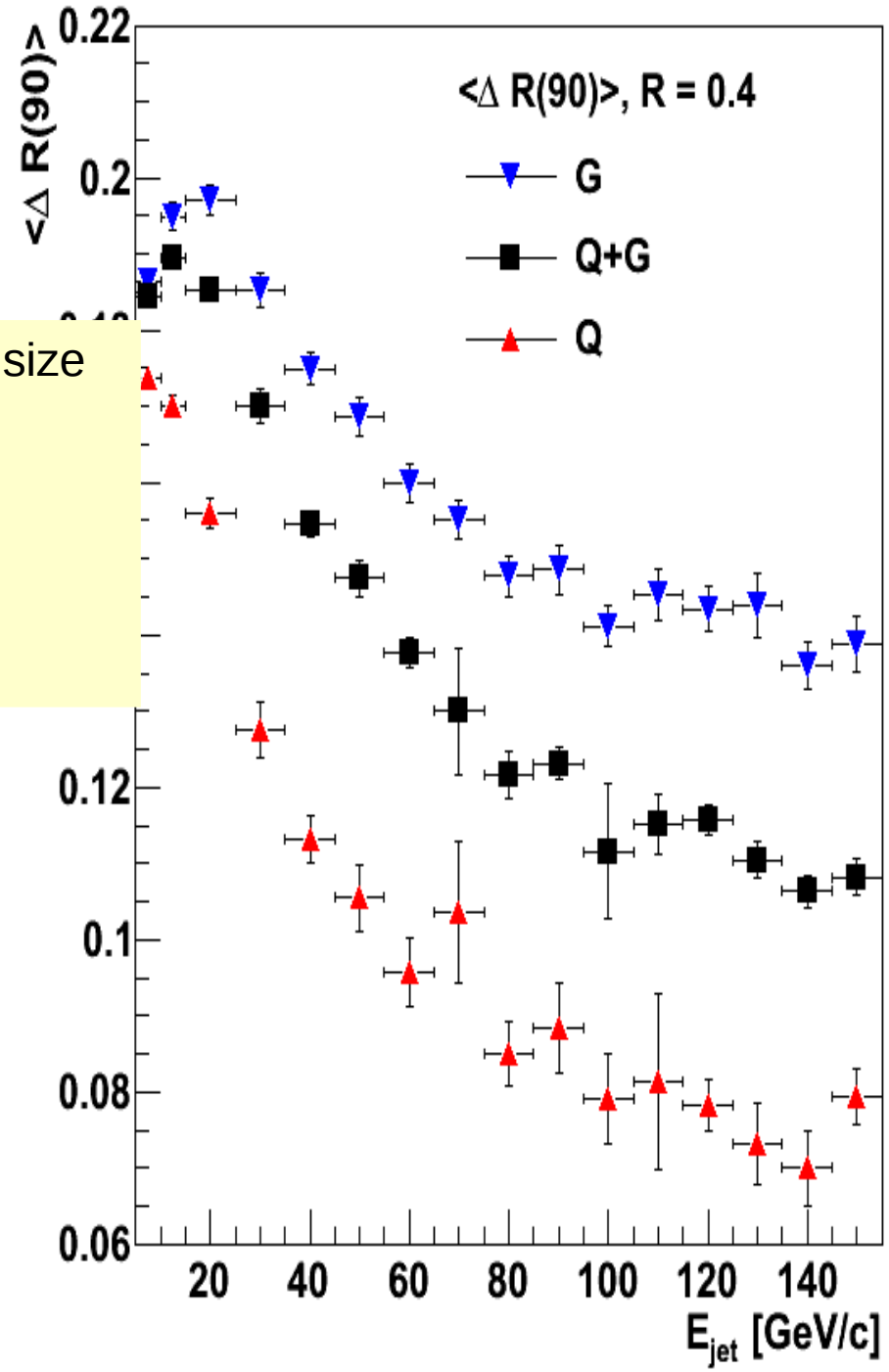
1st step: **extract the distribution of the variable and fit to obtain ΔR(90%)**

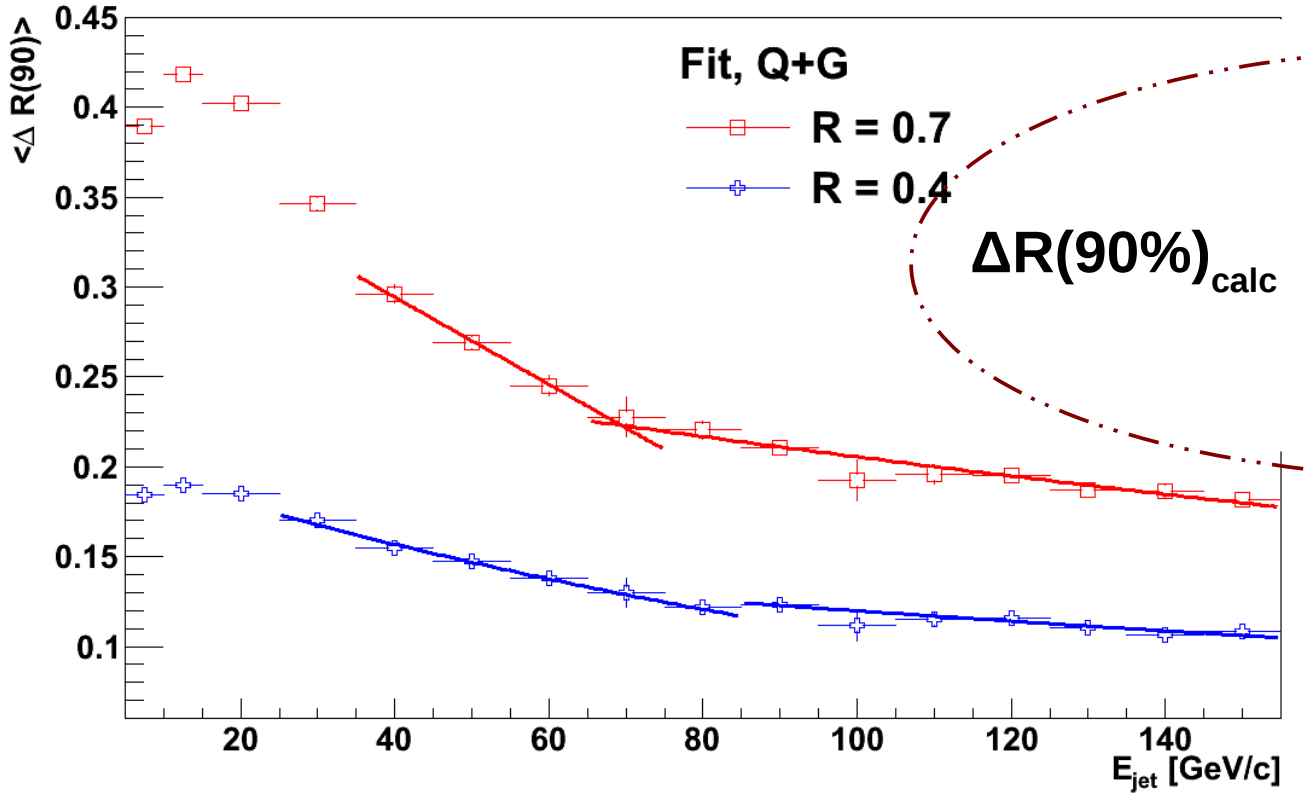


For gluons, sub-cone size is bigger

Closer to Q+G

Better separation at energies > 50 GeV/c





$\Delta R(90\%)_{calc}$

Fit fctions:

pol1 = A+BxE

exp = exp(A+BxE)

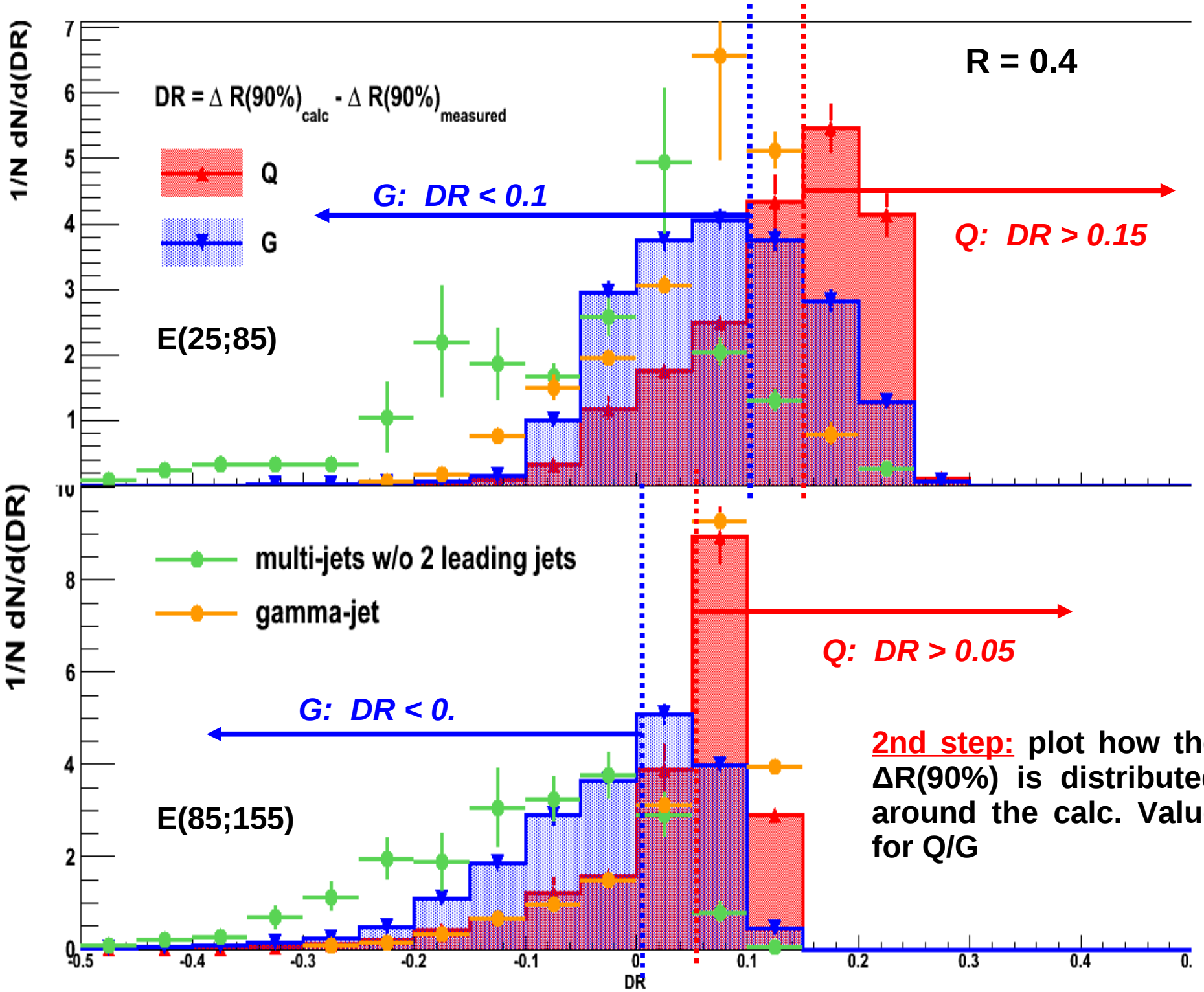
We get the variable as function of jet energy

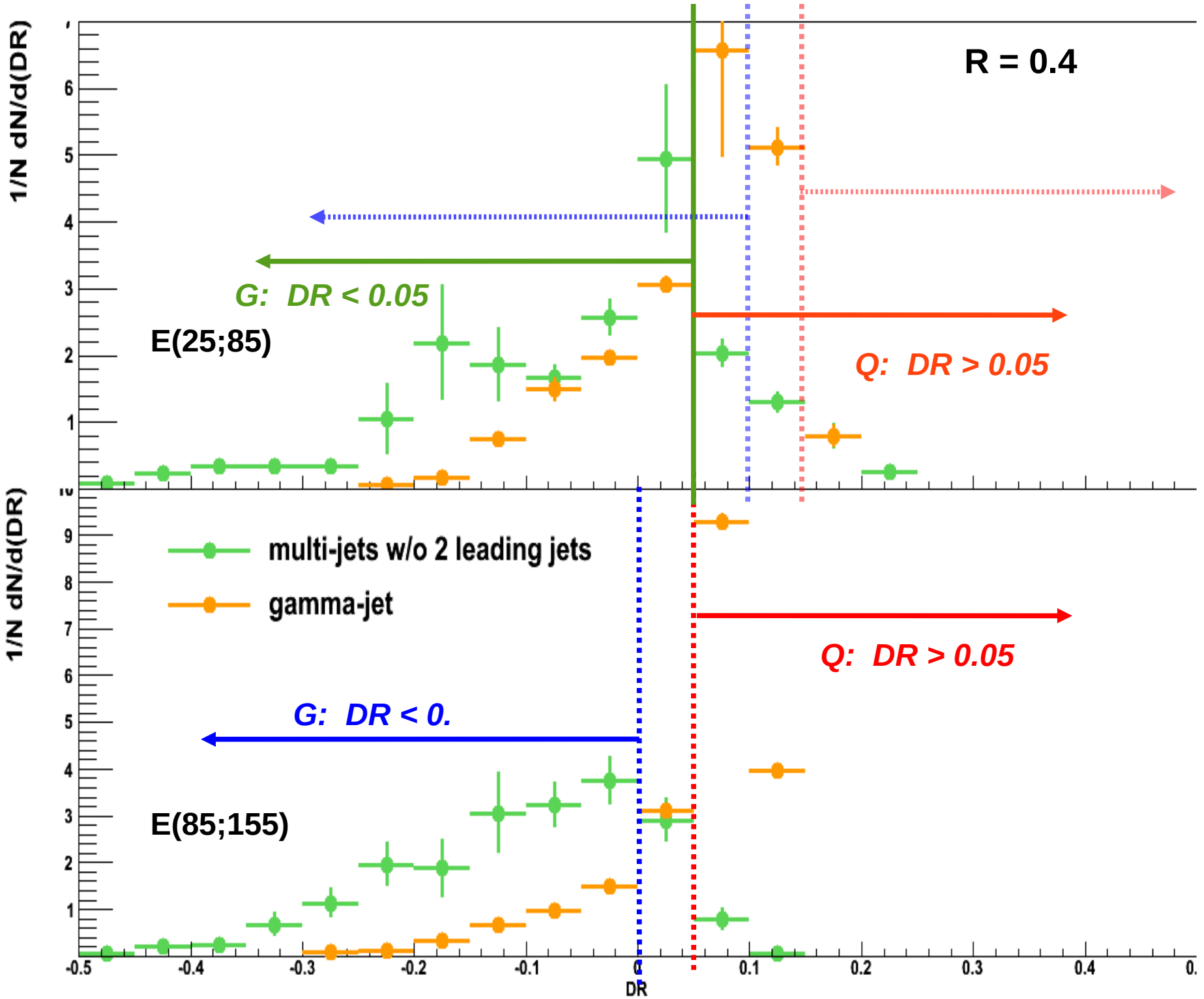
R = 0.7

E interval	Fit. fction	A	B	χ^2/Ndf	Prob
(35;75)	*pol1*	*0.3913 +/- 0.0159*	*-0.002424 +/- 0.000309*	*0.6188/2*	*0.733*
(65;155)	*exp*	*-1.316 +/- 0.035*	*-0.002666 +/- 0.000297*	*3.658/7*	*0.8183*

R = 0.4

E interval	Fit. fction	A	B	χ^2/Ndf	Prob
(25;85)	*exp*	*-1.59 +/- 0.02*	*-0.006556 +/- 0.000465*	*3.138/4*	*0.535*
(85;155)	*exp*	*-1.878 +/- 0.049*	*-0.002438 +/- 0.000401*	*3.97/5*	*0.5537*


R = 0.4
DR = Δ R(90%)calc - Δ R(90%)measured
Q
G
G: DR < 0.1
Q: DR > 0.15
E(25;85)
1/N dN/d(DR)
multi-jets w/o 2 leading jets
gamma-jet
Q: DR > 0.05
G: DR < 0.
E(85;155)
DR
2nd step: plot how the ΔR(90%) is distributed around the calc. Value for Q/G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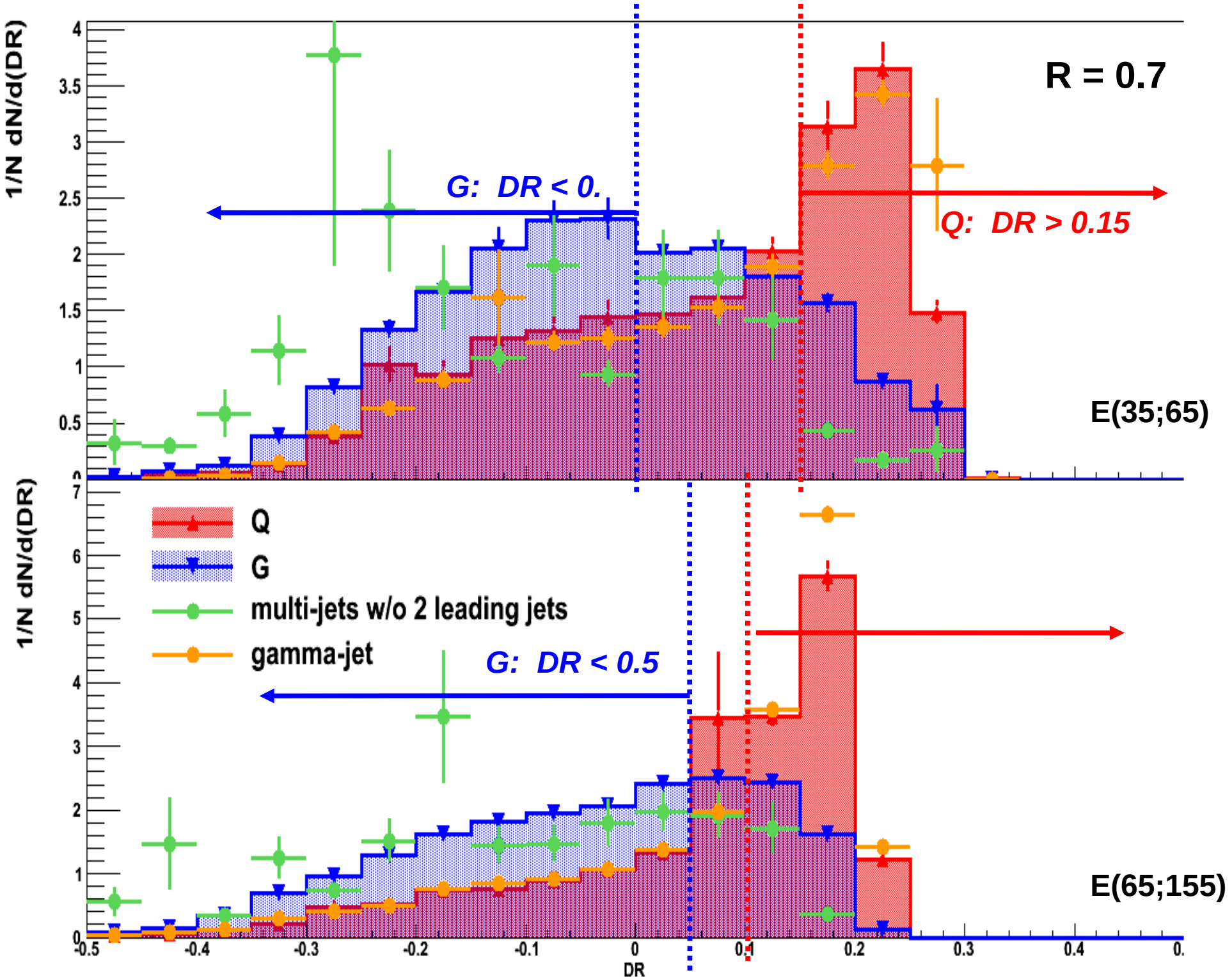
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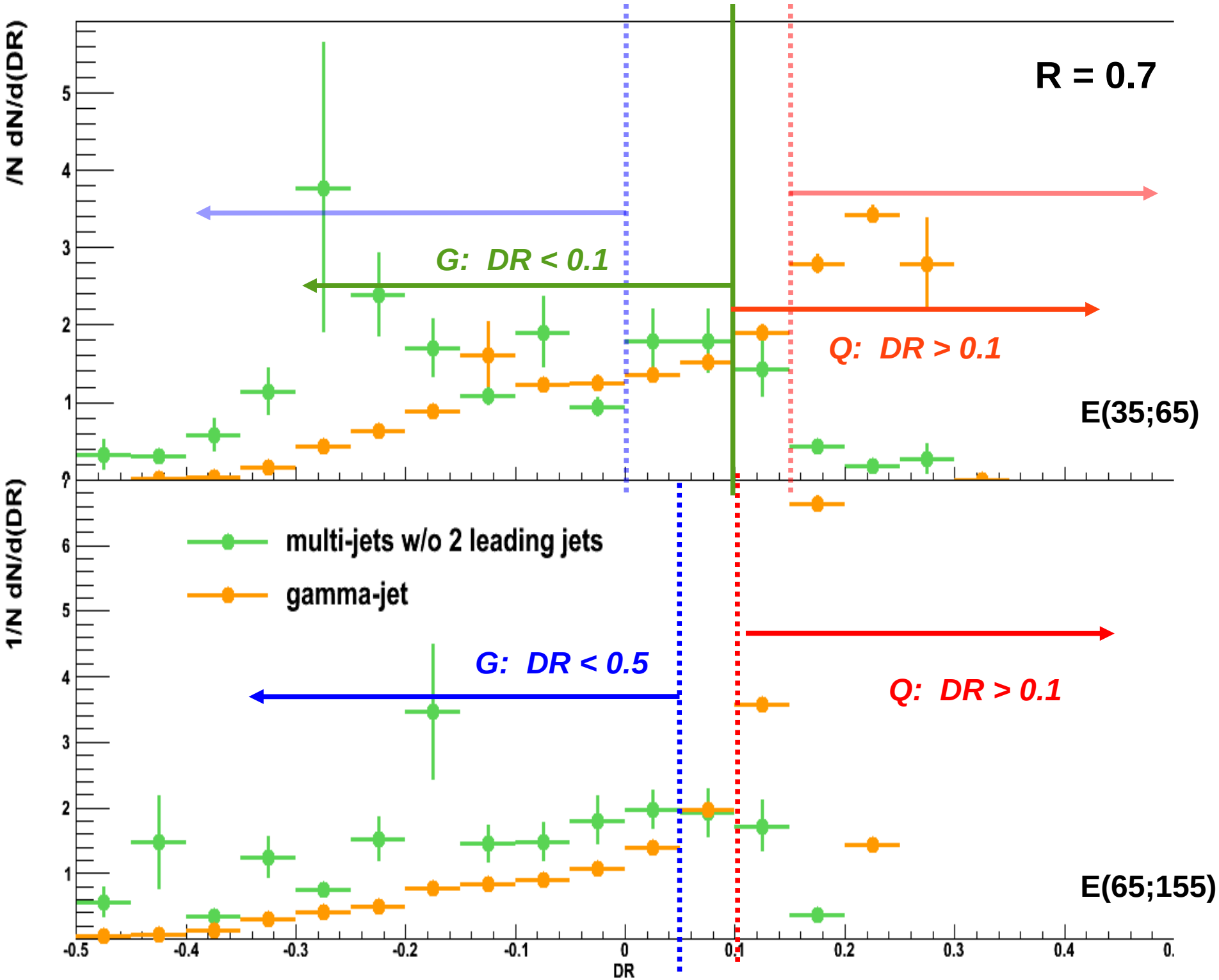
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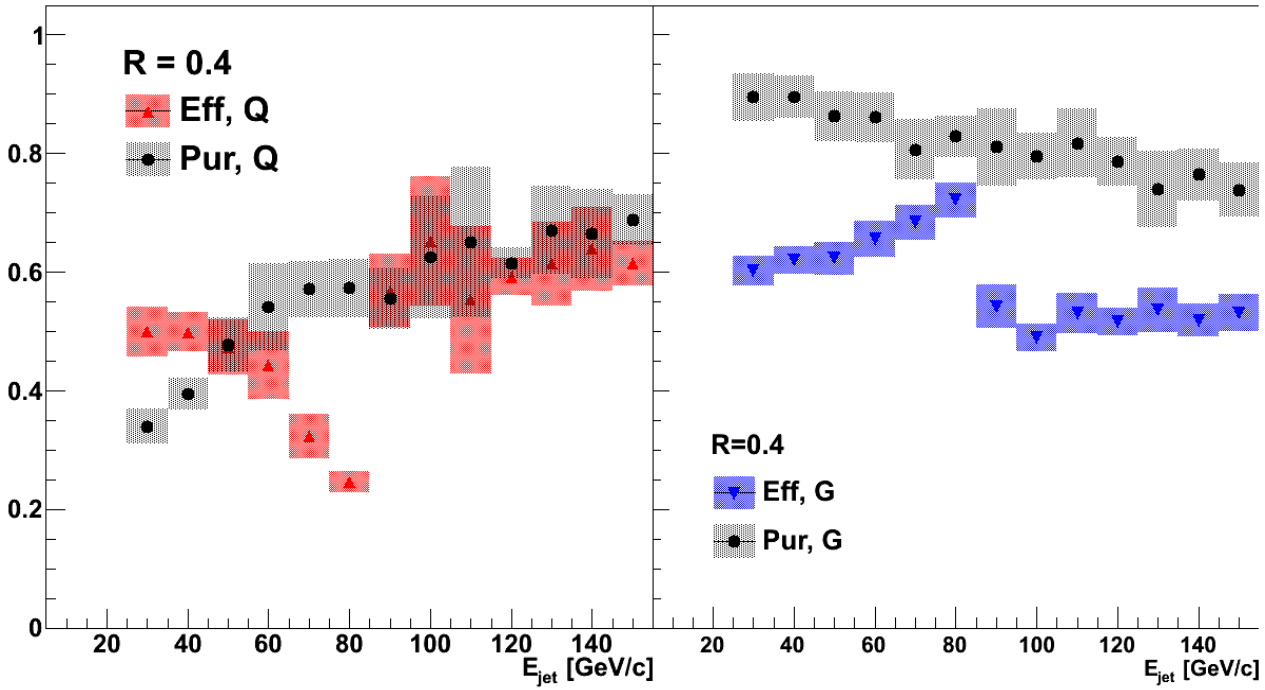

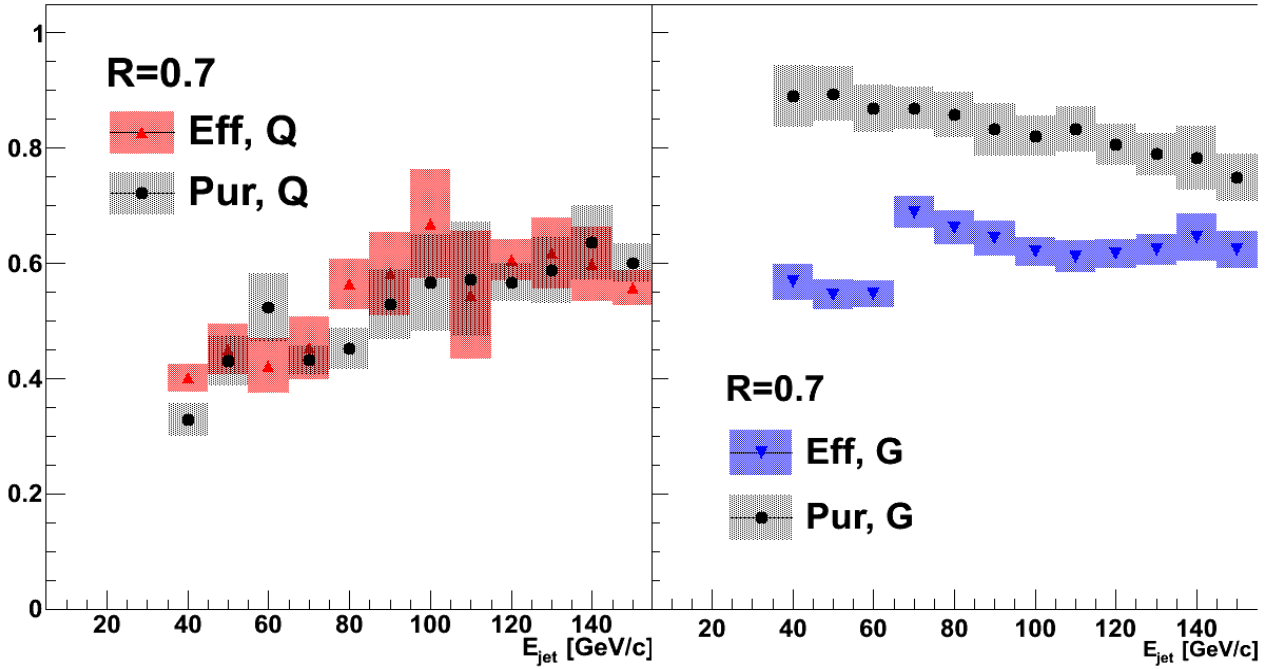

Performance

Apply the cuts on the two reconstructed leading jets.

In case of Quarks, the purity of the selection visibly rises with energy and the performance in general gets better.

For Gluons, the purity slightly decreases towards higher energies. But thanks to gluon dominance in the sample, we still reach high values of purity.

$$Eff = \frac{\sum \left(Q_{cut} \wedge Q_{MC} \right)}{\sum Q_{MC}}$$

$$Pur = \frac{\sum \left(Q_{cut} \wedge Q_{MC} \right)}{\sum Q_{cut}}$$

Summary

We introduced a method that can be used to identify Q/G jets in pp collisions

Although we showed a MC study, **experimental data offers an opportunity to define cuts using the "clean" production channels** of Quark and Gluon jets – ***multi-jets events, gamma-jet***

Such approach allows to **study the properties of leading jets based on the parton type in various topologies**

Next steps...

1) Fine tune method on data from LHC.
2) Study properties of such identified jets
   - Identified hadron spectra
   - Charged multiplicity
3) Investigate possibility to ID jets in HI

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Thank you!