Investigation of jet substructure

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Outline

1. Heavy ion collisions
2. Jets
3. My research and results

Heavy ion collisions

- **New state of matter (QGP) produced for an *extremely* short time**

  1-10 fm/c ≈ 10^{-23} - 10^{-24}s
  proton radius - 1 fm

- ***Extremely* hot: T_{LHC} ≈ 300 MeV ≈ $3 \cdot 10^{12}$ K**

  Sun surface: 6000 K
  Sun center: $15 \cdot 10^{6}$ K

- ***Extremely* dense: 15-30 GeV/fm^3 → ≈ 10^{19} kg/m^3**

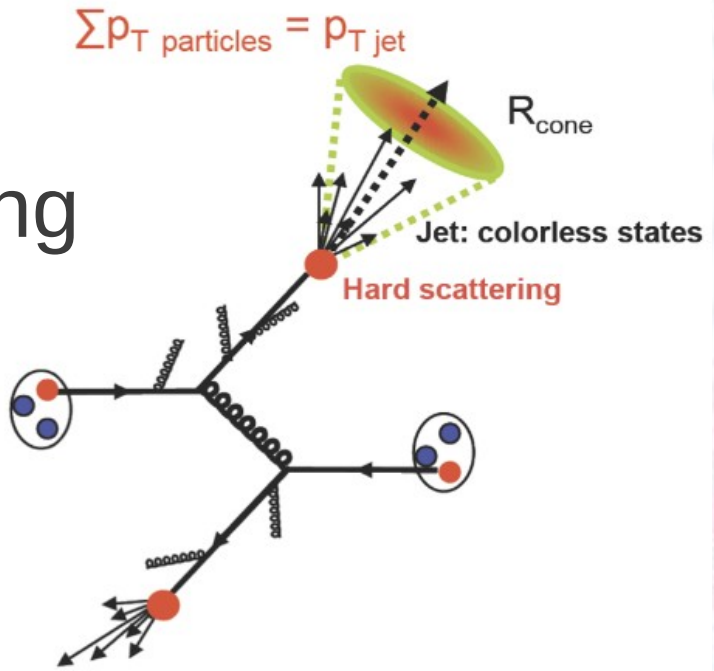
  nucleon≈1 GeV/fm^3
  water - 1 kg/m^3

- ***Extremely* high magnetic field: 10^{14} T**

  LHC magnet: 8.4 T
  Blast wave made in laboratory: 10^3 T
  Quasars: 10^6–10^9 T

Jets

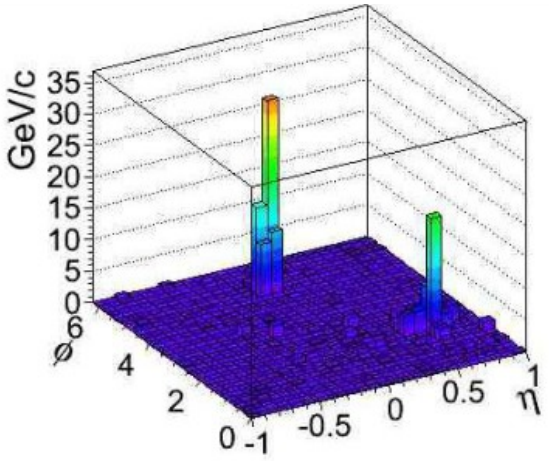
- Collimated spray of particles
- Starts from parton → u-jets, … , b-jets, g-jets
- Attractive QGP probe
  - Well understood in pQCD
- Expectations for jet quenching
  - Energy loss in QGP
  - Different structure
  - Different particle content

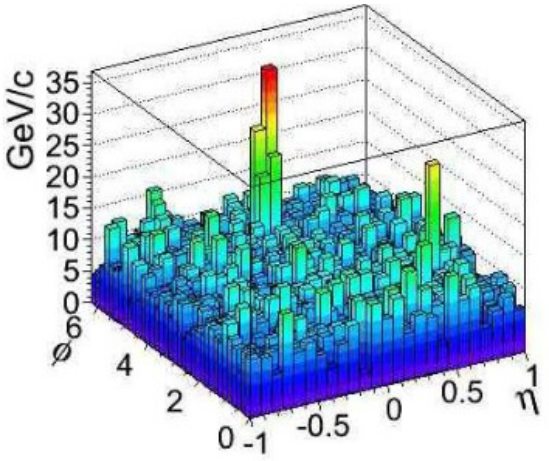


Goal of jet studies

- General goal: Find out for any jet
  - Flavour
  - 4-momentum of bearing parton
  - If it comes from QGP (quenched) or not
- My goal: find variable to discriminate between quark and gluon jets in heavy ion collisions
- Difficulty: background

p+p



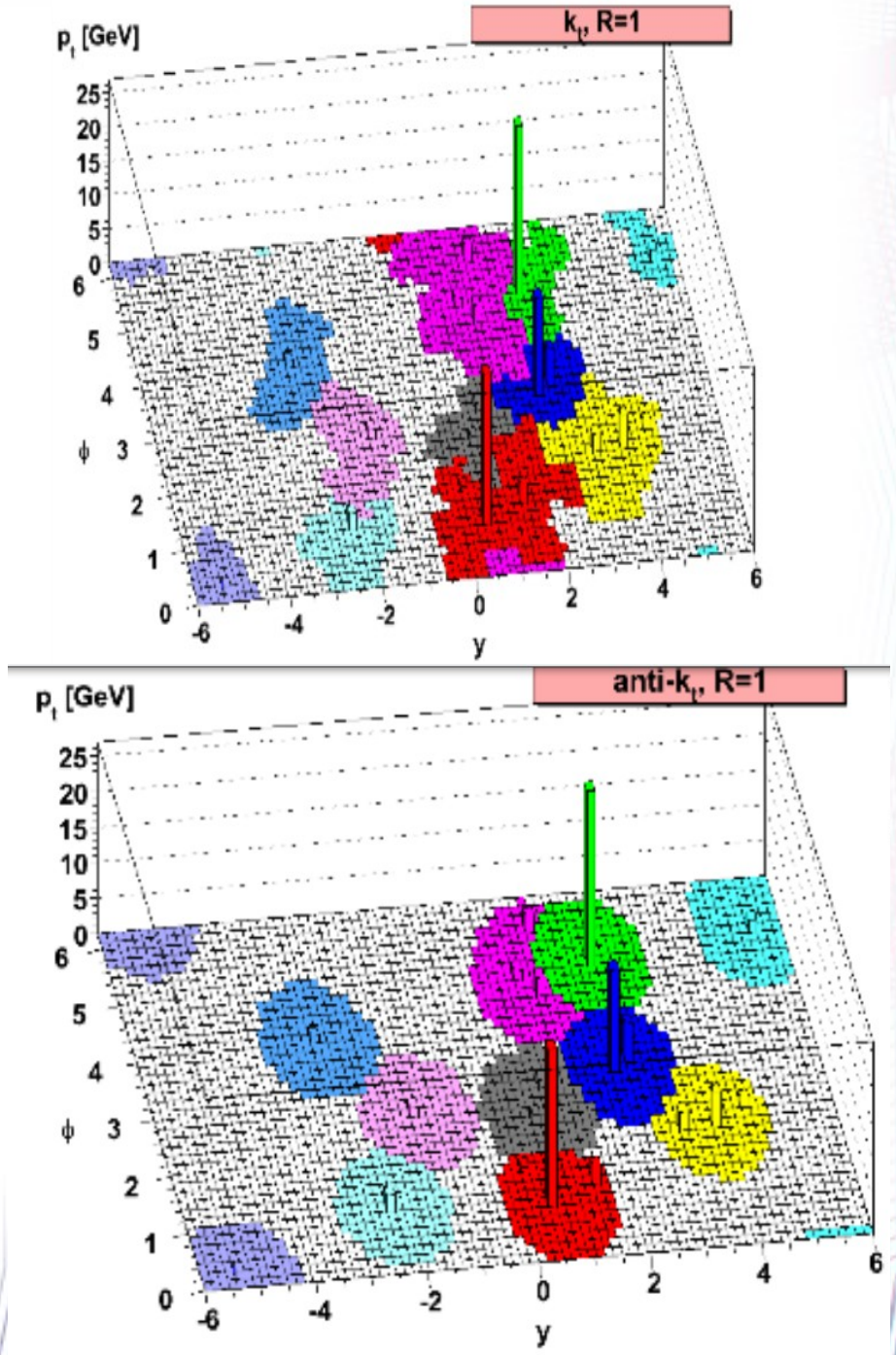


Pb+Pb, central collision

Jets

Defined operationally:

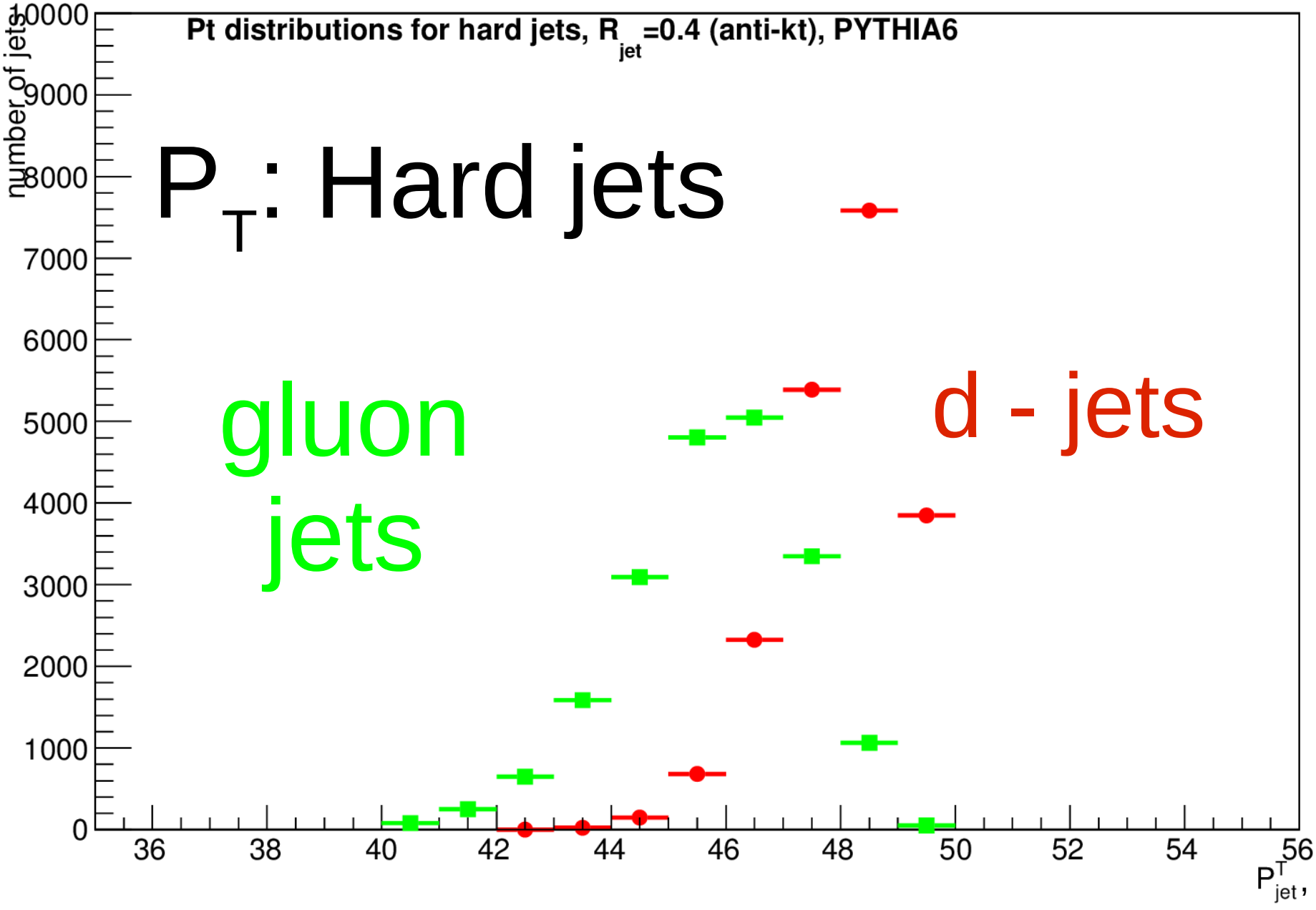
- Algorithm
- Resolution parameter R
- Recombination scheme



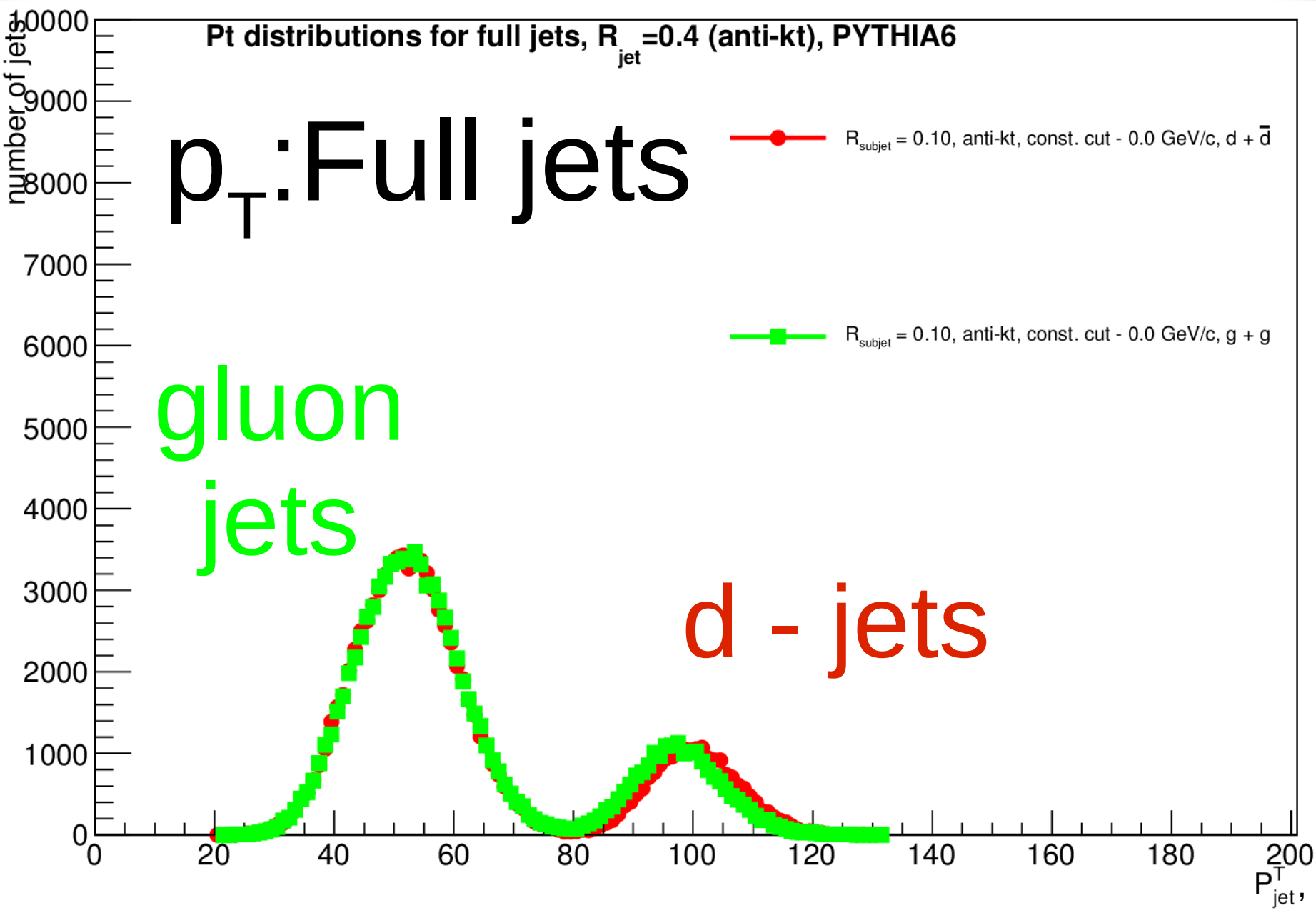
Toy Model: simulation of central Pb+Pb collision at LHC

- Generate **signal**: g- or d-jets with Pythia6/Pythia8
  - 2 hard gluons/$d\,\bar{d}$ per event
  - Each has P_T = 50 GeV
- Generate **background**
  - 2000 particles per event
  - Boltzmann p_T distribution, $\langle p_T \rangle$ = 0.7 GeV
  - Uniform η and φ
- Reconstruct jets: FastJet

Toy model


Pt distributions for hard jets, R_jet=0.4 (anti-kt), PYTHIA6
number of jets
P_T: Hard jets
gluon jets
d - jets
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
36
38
40
42
44
46
48
50
52
54
56
P_jet^T, GeV

Toy model


Pt distributions for full jets, R_jet=0.4 (anti-kt), PYTHIA6
number of jets
R_subjet = 0.10, anti-kt, const. cut - 0.0 GeV/c, d + d̄
R_subjet = 0.10, anti-kt, const. cut - 0.0 GeV/c, g + g
p_T:Full jets
gluon jets
d - jets
P_jet^T, GeV
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
20
40
60
80
100
120
140
160
180
200

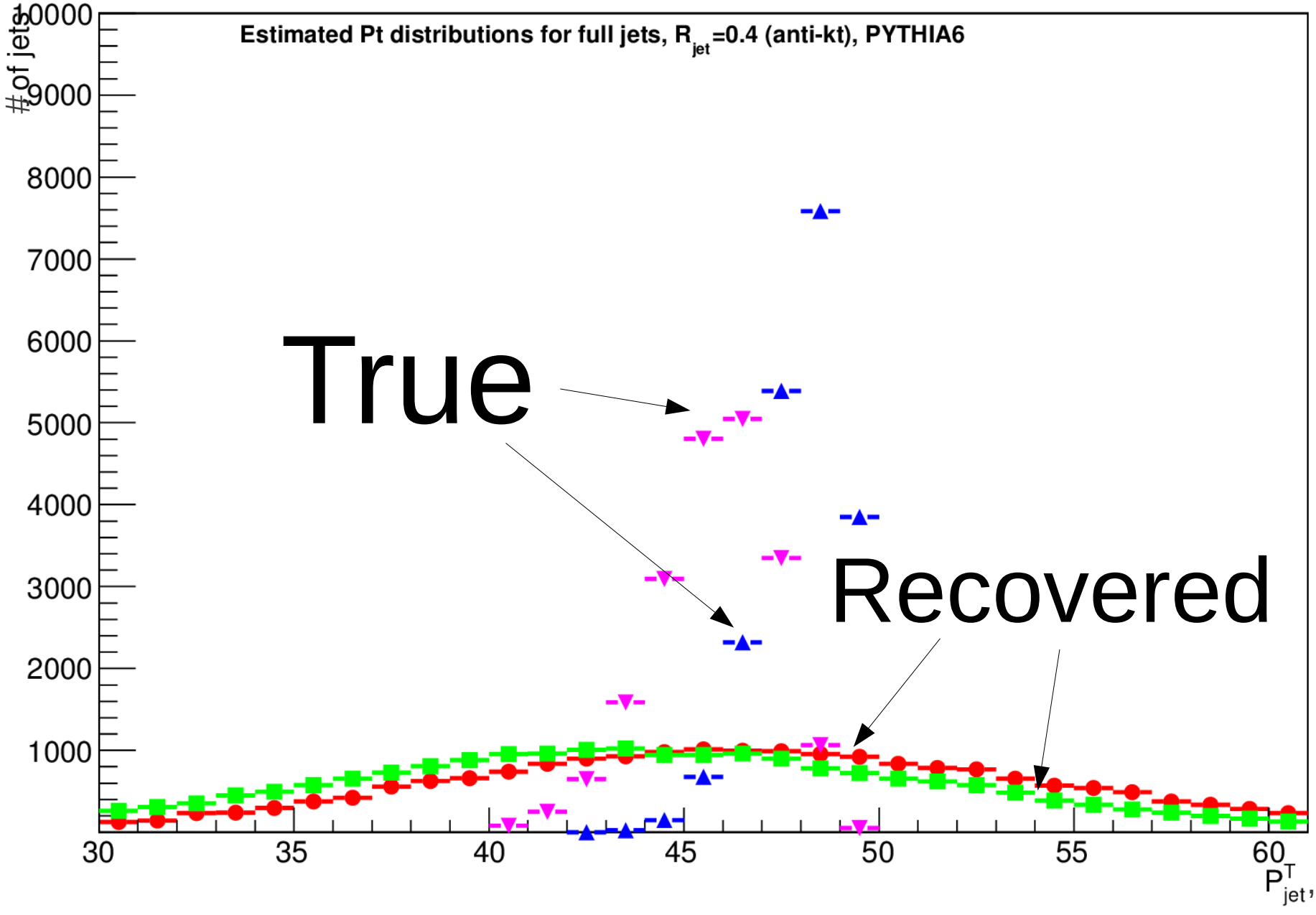
Background subtraction

ρ – estimated average background density
Estimated once per event.

A – jet area
Calculated for each jet.

$$P_T^{estimated}(jet) = P_T^{measured}(jet) - \rho A(jet)$$

Get back jet P_T

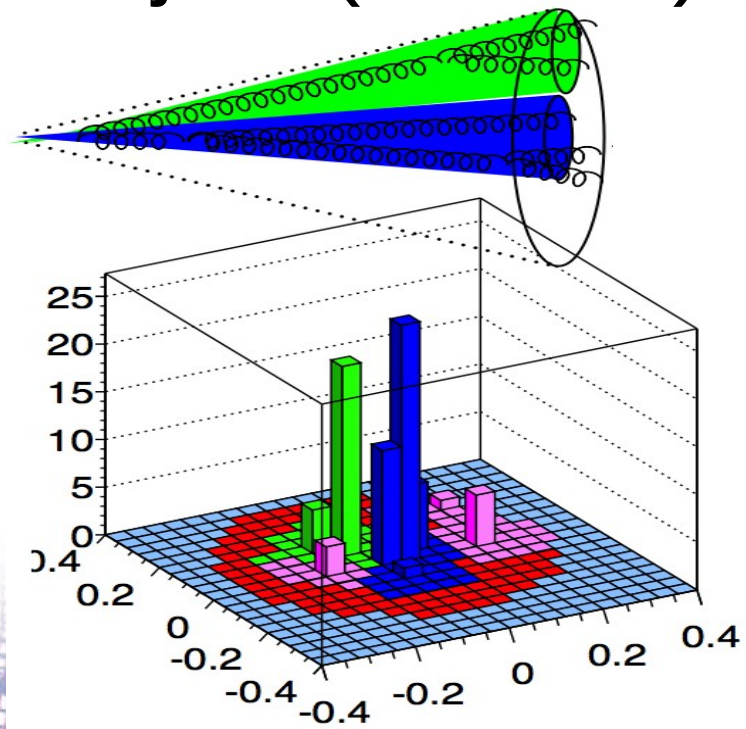


Leading subjet Z

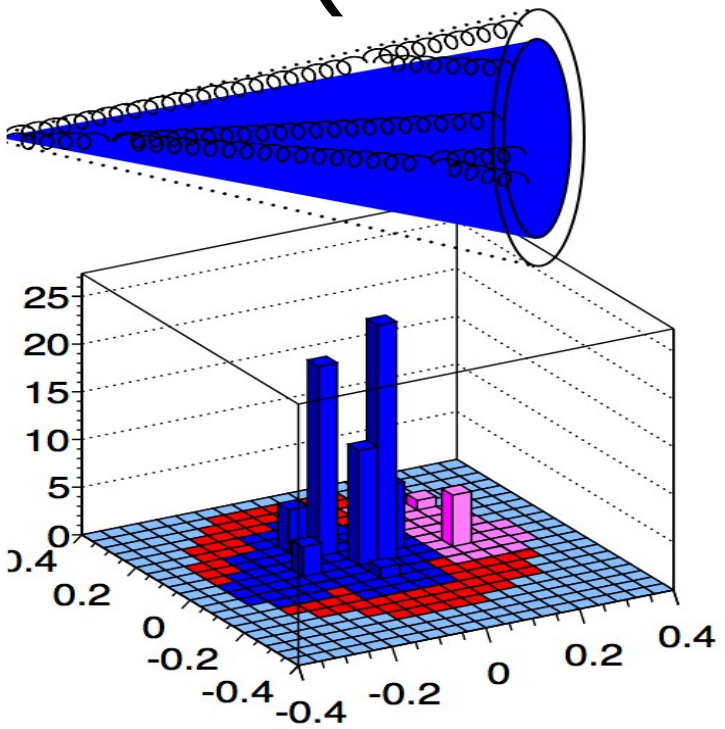
$$Z = p_T^{subjet} / p_T^{Jet}$$

Quark jets: expect larger Z
Gluon jets: expect smaller Z

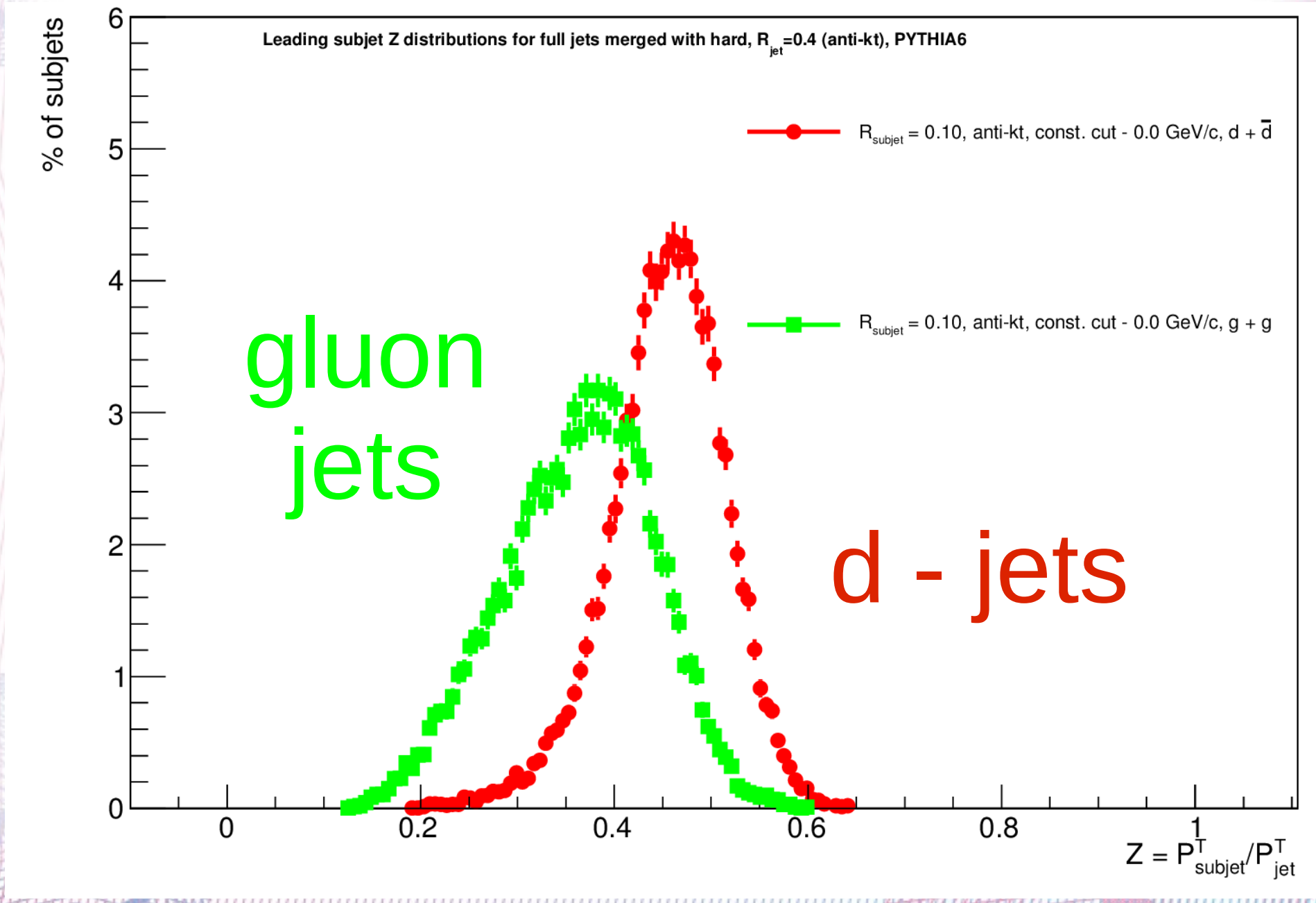
Subjets (R = 0.1)



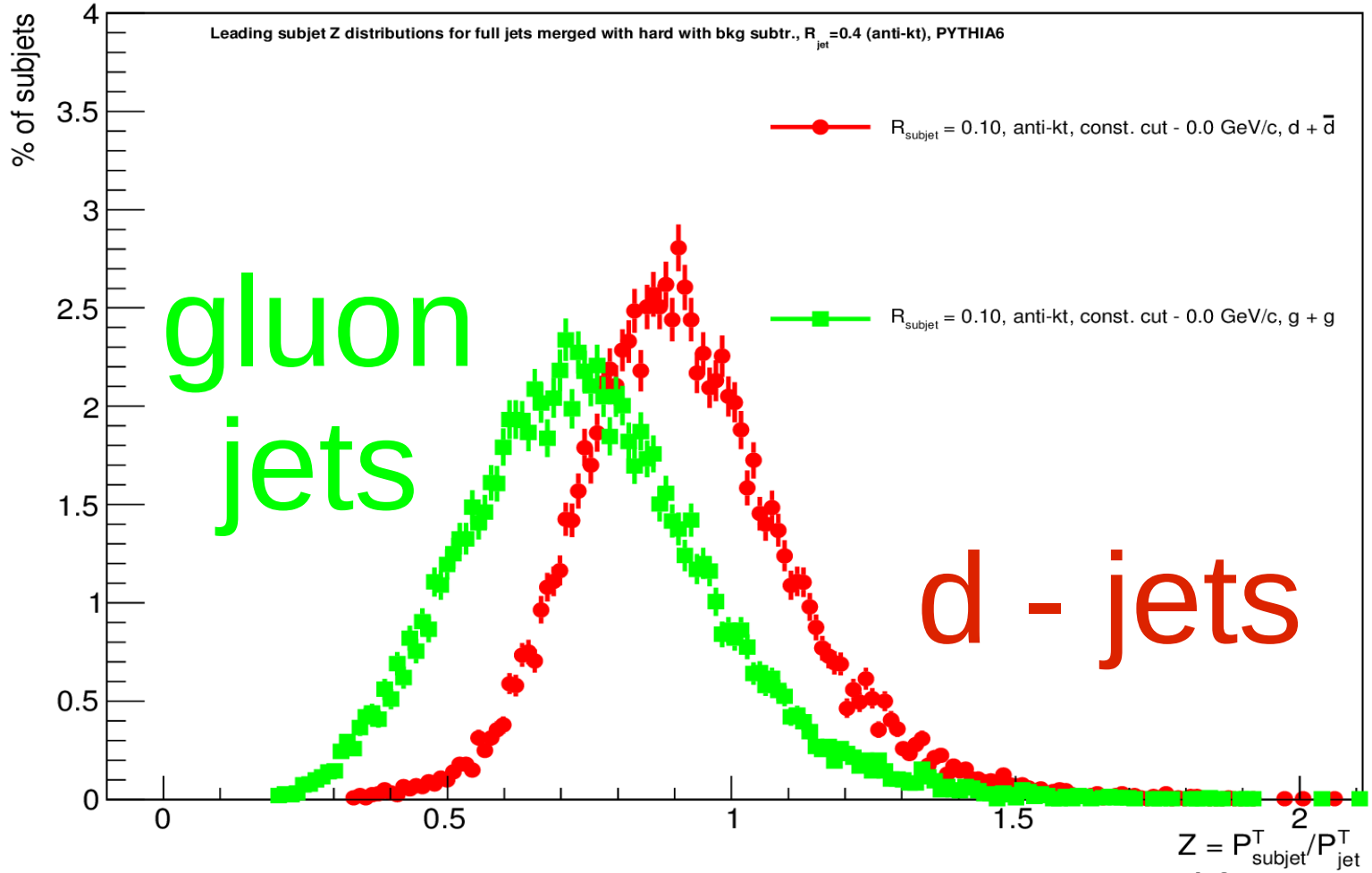
Jet (R = 0.4)



Separating q- and g-jets



Separating q- and g-jets after bkg subtraction



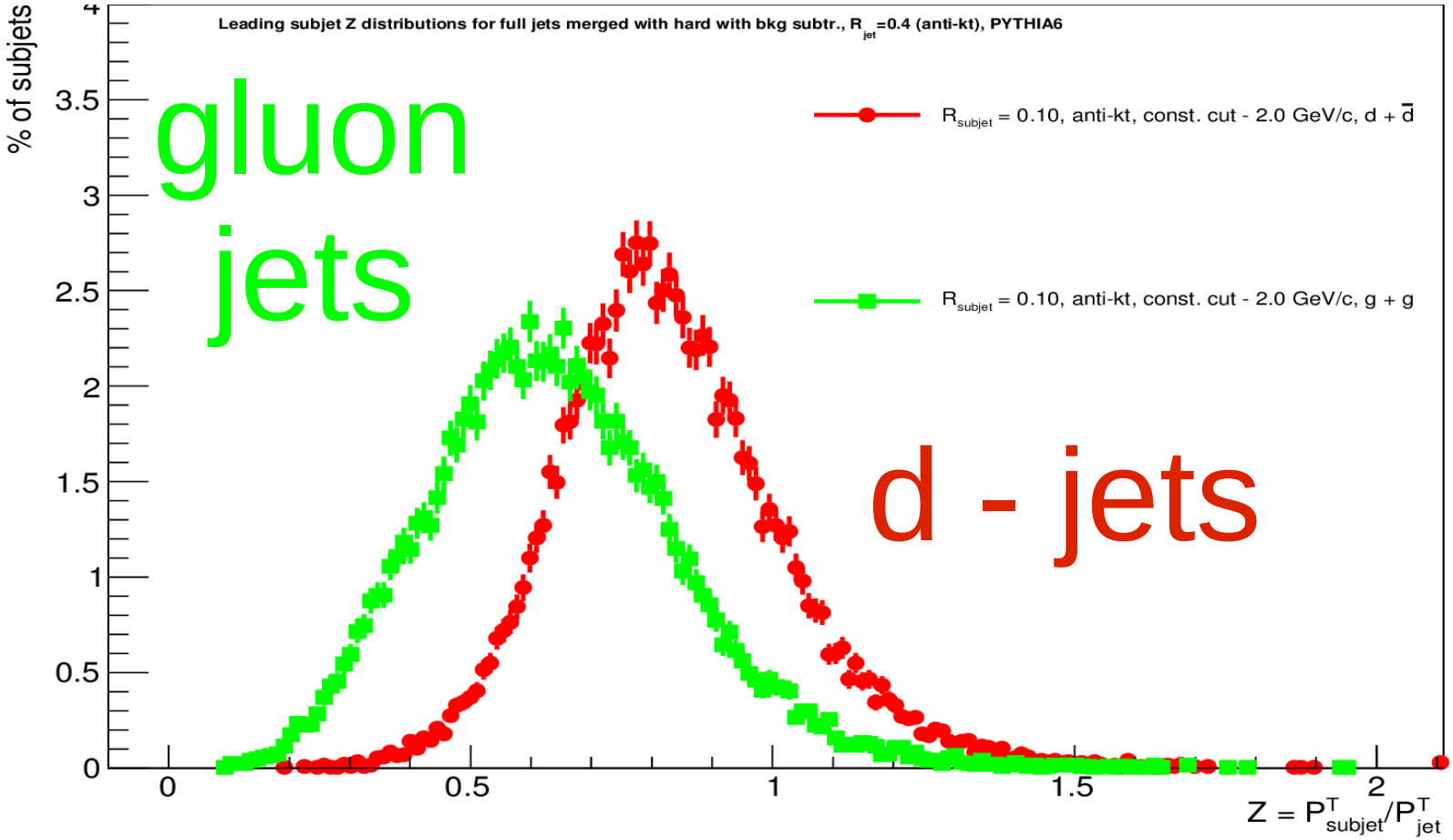
corrected for average bkg

$P_T^{estimated}(jet) = P_T^{measured}(jet) - \rho A(jet)$

Constituents cut

To avoid spacial background fluctuations we apply jet constituents P_T cut - 2 GeV.

Will separation hold?



Conclusions

- We modeled background similar to central heavy ion collisions
- Jets in heavy ion collisions corrected for average background
  - preserve their main qualitative subjet features - gluons vs quarks
  - leading subjet distributions are robust against high constituent cuts limiting the influence of heavy ion background fluctuations

Thank you for attention

Next steps

- Corrections for residual smearing (fluctuations)
- Simulations with realistic p_T spectrum and parton cocktail
- Studies with quenched MC models
- Applications in the data