LHC-ALICE実験における
クォークジェット・グルーオンジェット識別の研究

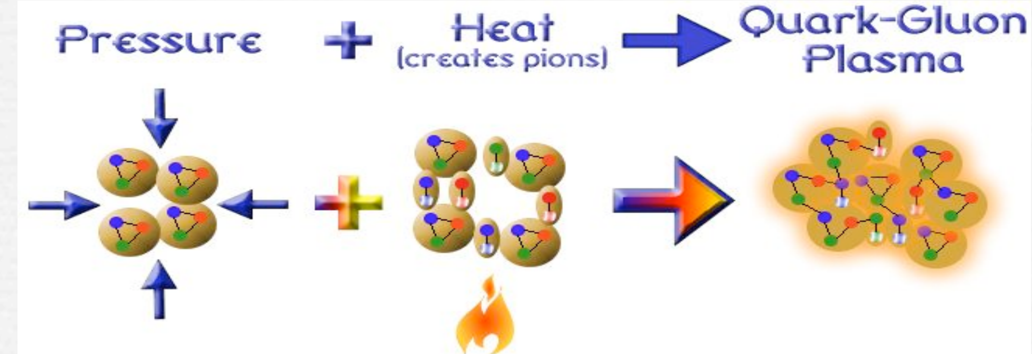
横山広樹 for the ALICE Collaboration

2010/03/20
日本物理学会第65回年次大会

Outline

- **導入**
  - Quark Gluon Plasma(QGP) ,LHC-ALICE実験
  - ジェット抑制効果
  - 研究動機
- **解析方法**
- **結果**
  - Quark-JetとGluon-Jetの違い
  - Likelihood法を用いたQuark/Gluon-Jetの識別
- **結論**

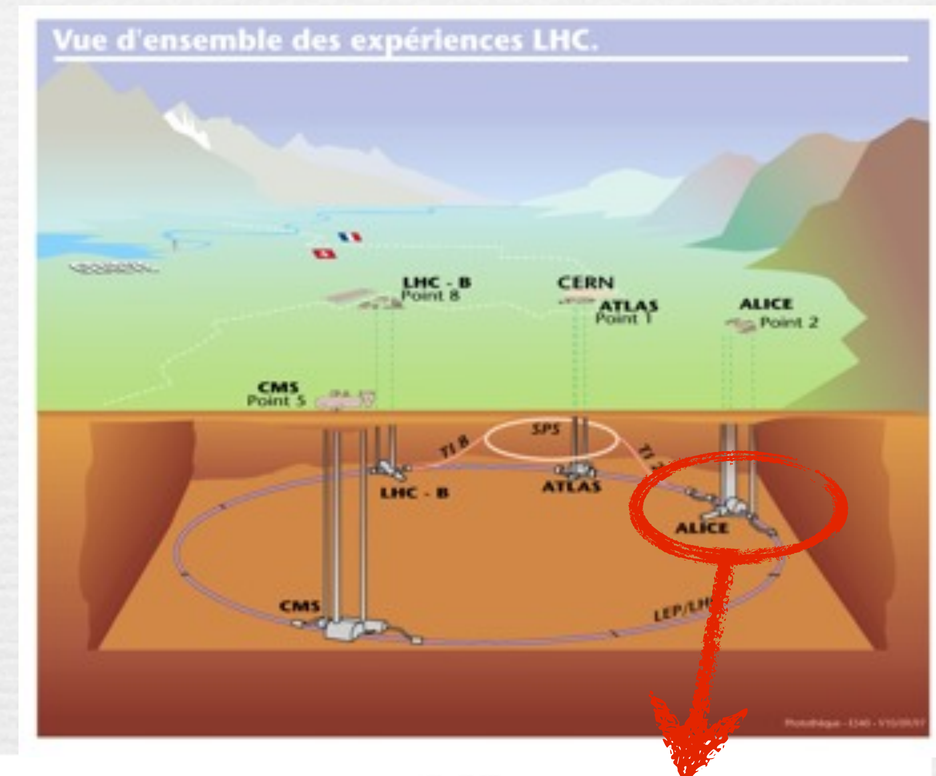
Quark Gluon Plasma(QGP)

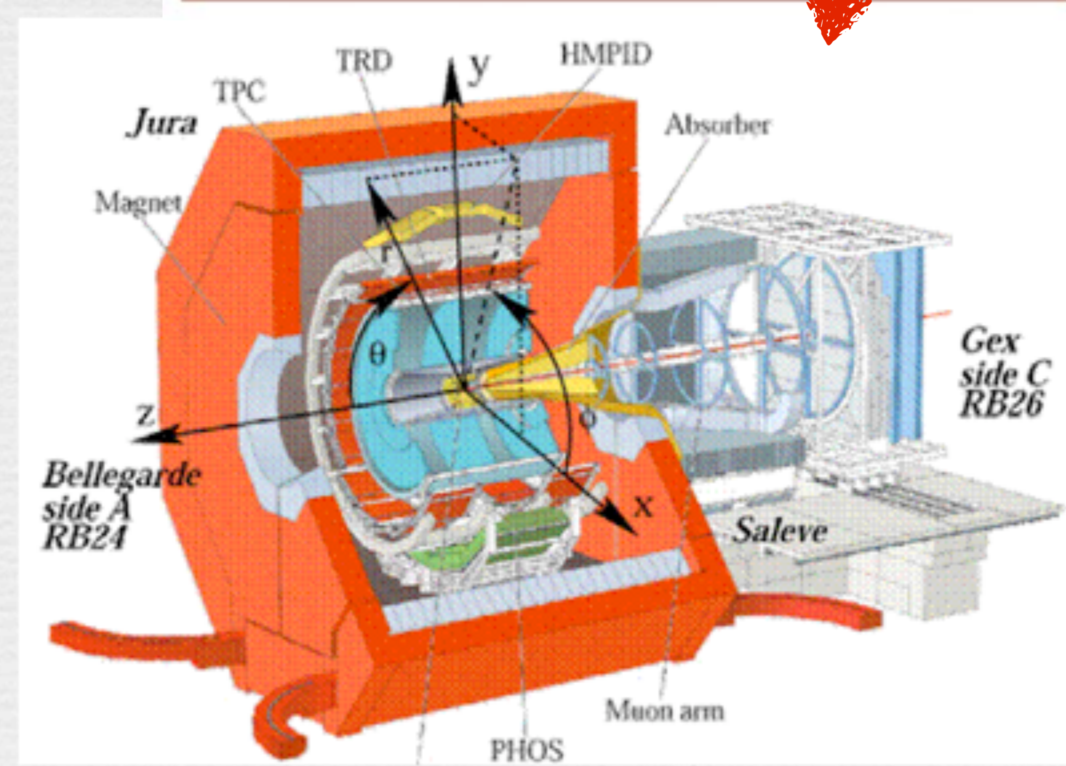


- 宇宙の進化の過程(~数μ秒)
  - 高温高密度物質の膨張・冷却
  - パートン物質からハドロン物質への相転移
  - クォーク・グルーオンプラズマ(QGP)

- Lattice QCD
  - T_c ~ 150-170 MeV
  - ε_c ~ 1 GeV/fm^3

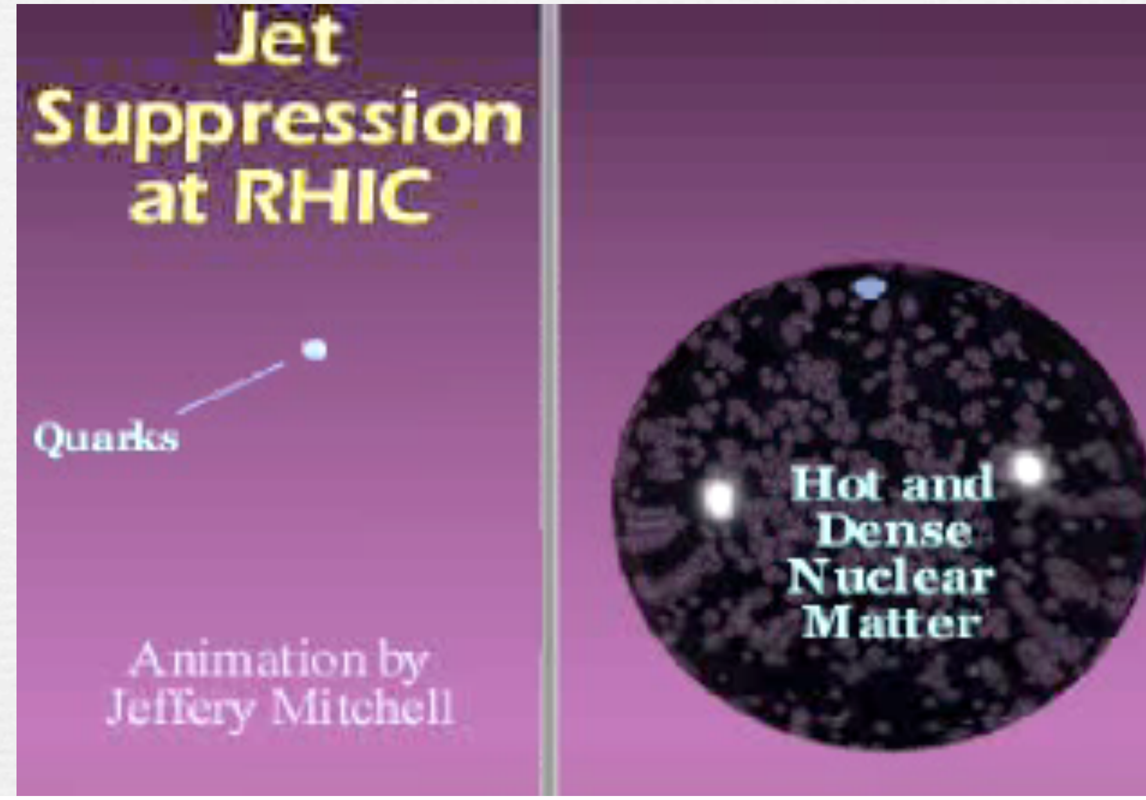
- 高エネルギー重イオン衝突実験
  - 高温高エネルギー密度状態の再現
  - LHC-ALICE 実験
    - $\sqrt{s_{NN}}$ = 5.5TeV Pb+Pb
    - $\sqrt{s}$ = 14 TeV p+p

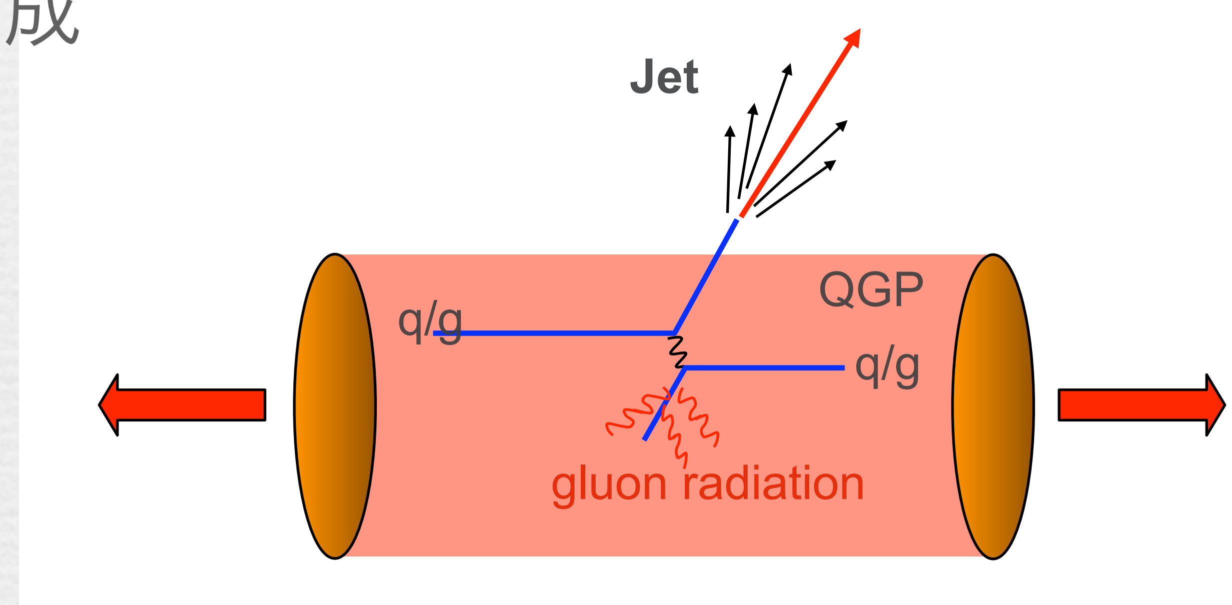




ジェット抑制効果

- QGP中でのパートンのエネルギー損失
- Δφ=π 方向のジェットの消失(RHIC)
- LHCでの予測
  - 世界最大の衝突エネルギー
  - 多数の高エネルギージェットの生成
    - ~200GeV(Inclusive-Jets)
  - QGPを貫通

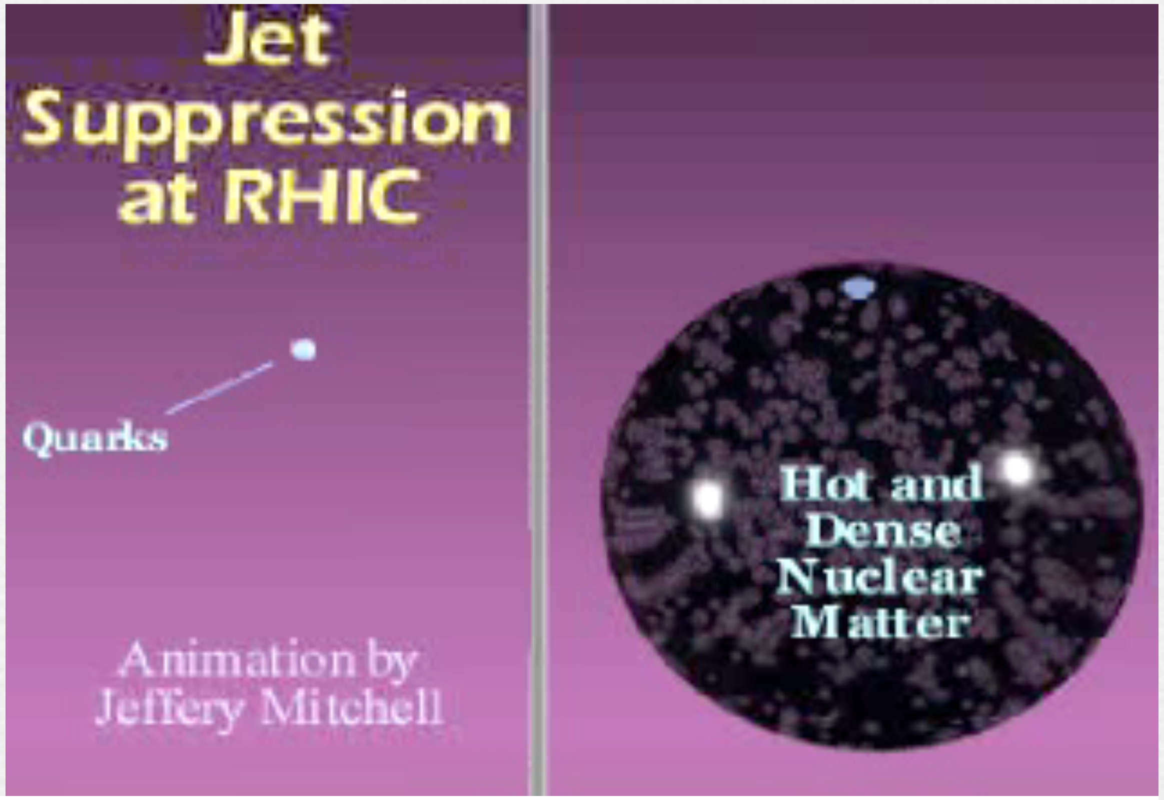


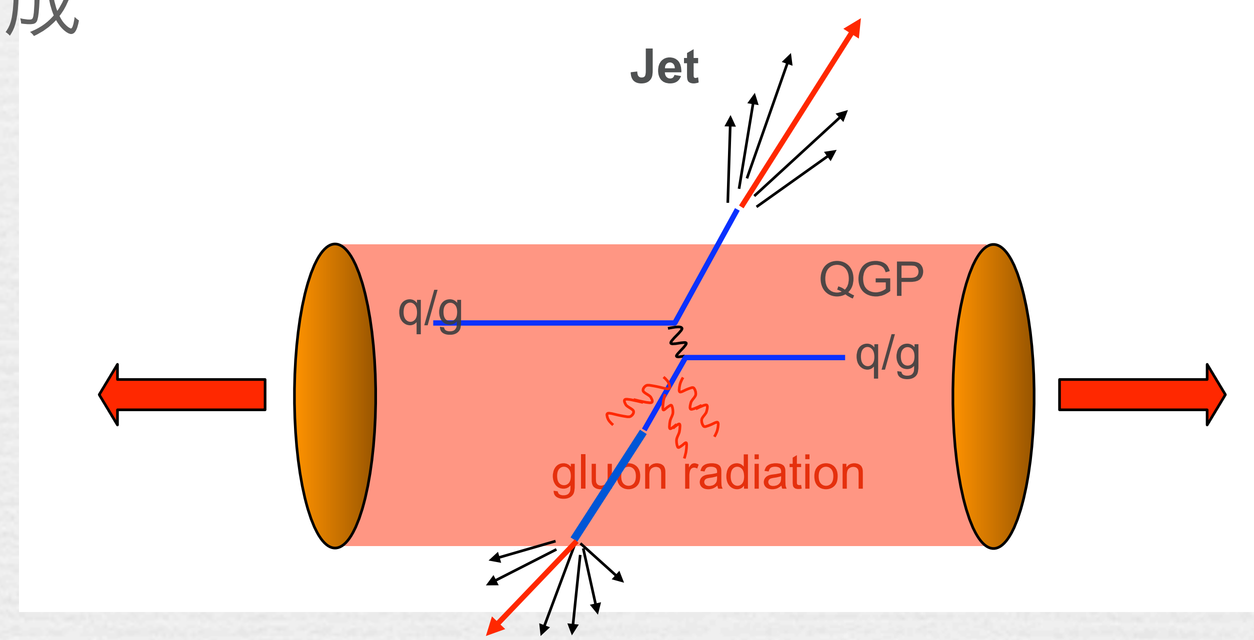


QGP中でのパートンのエネルギー損失機構の理解のためにジェット事象は有効である

ジェット抑制効果

- QGP中でのパートンのエネルギー損失
- Δφ=π 方向のジェットの消失(RHIC)
- LHCでの予測
    - 世界最大の衝突エネルギー
    - 多数の高エネルギージェットの生成
        - ~200GeV(Inclusive-Jets)
    - QGPを貫通





QGP中でのパートンのエネルギー損失機構の理解のためにジェット事象は有効である

研究動機

- **QGP中でのパートンのエネルギー損失機構の解明**
  - パートンのエネルギー損失の測定
    - →Di-Jet, γ-Jet
  - **パートン種の推定**

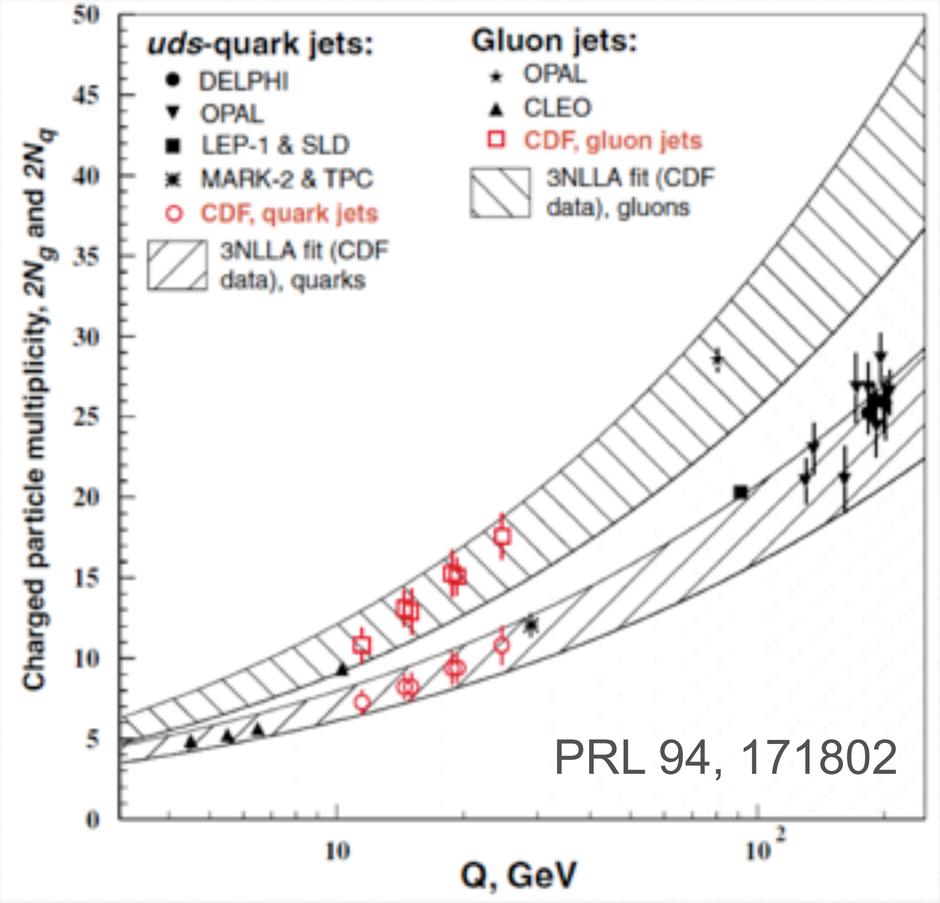
- **Parton-IDの可能性**
  - **ジェット内粒子分布を用いたQuark/Gluon-Jet識別**
    - Likelihood法

シミュレーションを用いたQuark/Gluon-Jet識別の可能性の評価

Q-PYTHIA (AliRoot framework)

- PYTHIA + パートンのエネルギー損失
  - 0-10% central AA collision
  - BDMPS based energy loss
  - $\langle \Delta E \rangle_{BDMPS} \propto \alpha_S C_R \langle \hat{q} \rangle L^2$
    - qhat [GeV^2/fm] : transport coefficient(モデルパラメータ)
    - L [fm] :パートンの通過距離
    - C_A=3 (Gluon)
    - C_F=4/3(Quark)

- Quark/Gluon-Jetの違い(CDF)
  - N_g/N_q~1.5



Analysis Flow & Analysis Conditions

PYTHIA p+p 14TeV

- AliRoot v4-17-01
  - Pythia6, kPyJets
  - (2→2 jet production)

Q-PYTHIA Pb+Pb 5.5TeV

- AliRoot v4-17-01
  - qPythia, kPyJets
  - qhat=50GeV^2/fm
  - 0-10% central

fastjet anti-kt (Jet Reconstruction)

- Fastjet(http://www.lpthe.jussieu.fr/~salam/fastjet/)
  - pT cut of single particle = 0.5GeV/c
  - Using detectable particles in ALICE
  - Jet radius parameter : R=0.4

HIJING Pb+Pb 5.5TeV

Jet Separation using Likelihood method

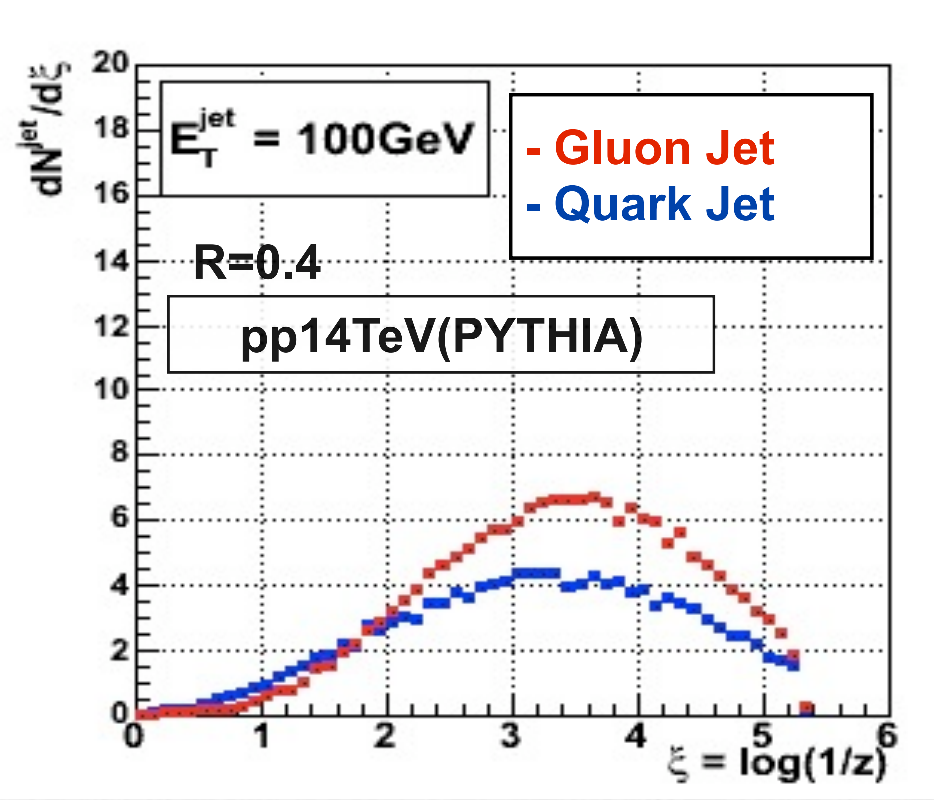
- ✓ Selection of Quark/Gluon-Jet sample
  - ✓ The largest energy jet in $dR_{parton}<0.5$
    - ✓ dR_{parton} : distance from initial parton
    - ✓ $dR_{parton} = \sqrt{((\eta_{jet}-\eta_{parton})^2 + (\phi_{jet}-\phi_{parton})^2)}$

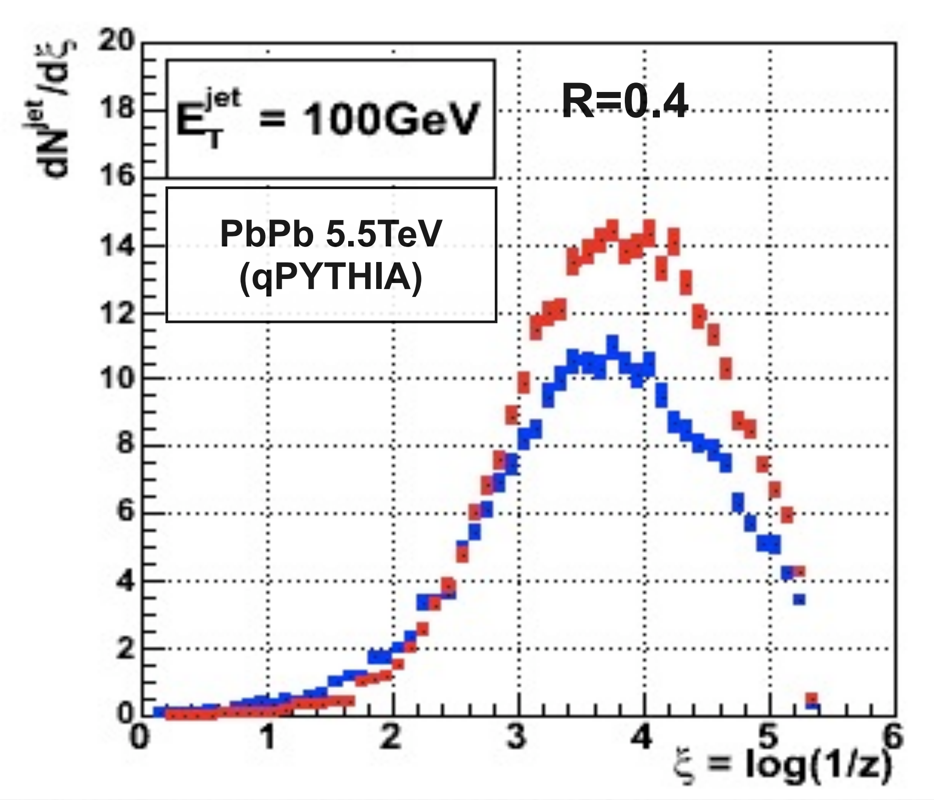
Quark-JetとGluon-Jetの違い

ξ@Et100GeV	1	2	3	4	5
pT[GeV/c]	36.8	13.5	5.0	1.8	0.7

$$\xi = \log\left(\frac{1}{z}\right) = \log\left(\frac{E_T^{jet}}{p_T}\right)$$

- 破砕関数
  - higher hump-back plateau
    - Quenched-Jets
    - Gluon-Jets

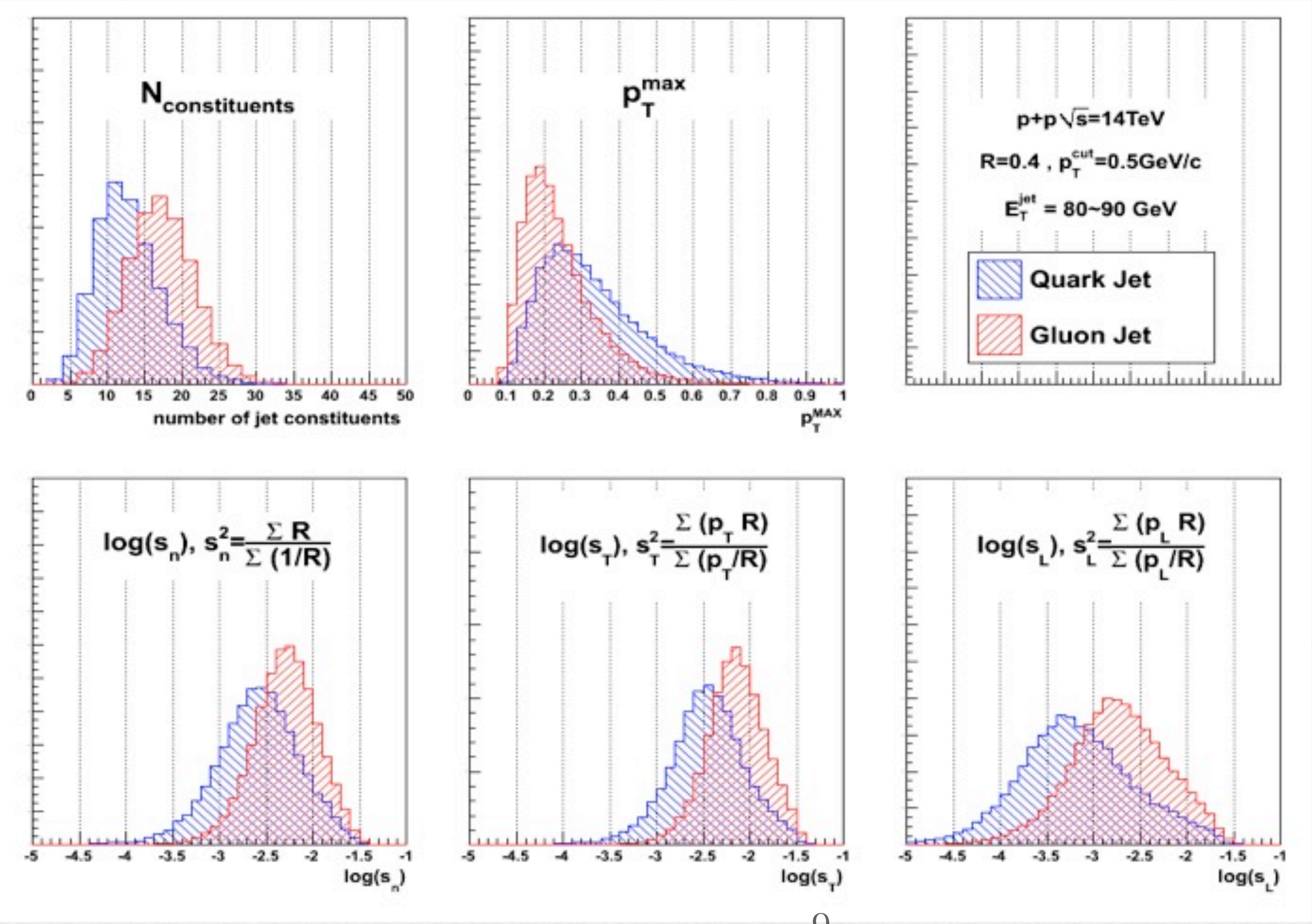




Gluon-JetはQuark-Jetに比べ
ジェット内の低(高)運動量粒子が多い(少ない)

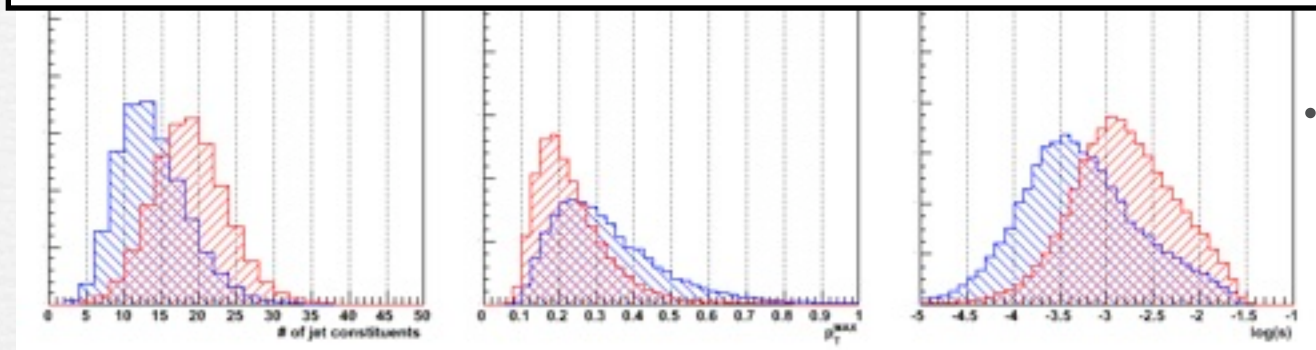
Quark-JetとGluon-Jetの違い

- Likelihood法で用いるパラメータ
  - ジェット内粒子数
  - 粒子の最大横運動量
  - ジェットの半径方向の拡がり

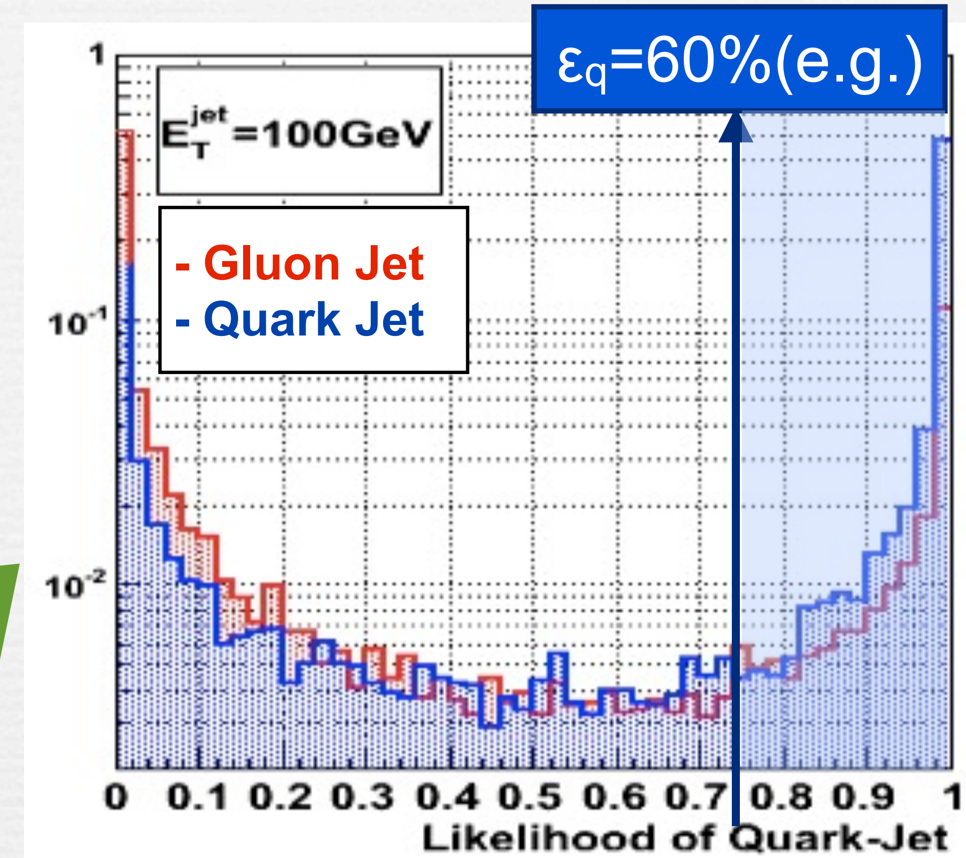


Likelihood法(quark-Jet trigger)

$$P^{(i)}_{quark}, P^{(i)}_{gluon} : probability\_of\_ith\_parameter$$



・・・



$$likelihood = \frac{P_{quark}}{P_{quark} + P_{gluon}}$$

$$P_{quark} = \prod_{i=1}^{N} P^{(i)}_{quark}$$

$$P_{gluon} = \prod_{i=1}^{N} P^{(i)}_{gluon}$$

$$\epsilon_{quark} = \int_{L_{\epsilon_{quark}}}^{1} \frac{1}{N_{quark}} \frac{dN_{quark}}{dL} dL$$

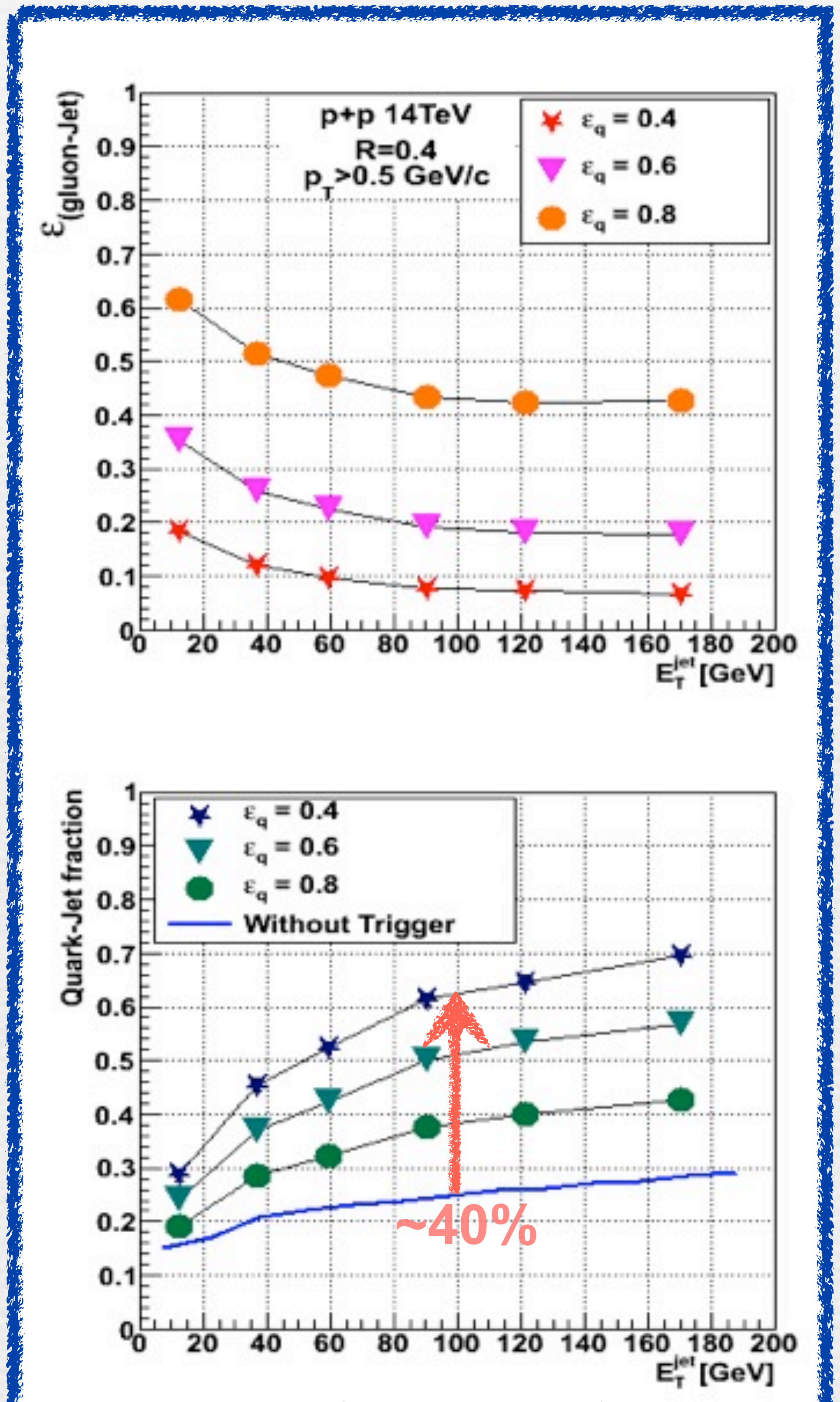
$$\epsilon_{gluon} = \int_{L_{\epsilon_{quark}}}^{1} \frac{1}{N_{gluon}} \frac{dN_{gluon}}{dL} dL$$

- Gluon-Jet誤識別能率
- →Quark/Gluon-Jet識別の強さ

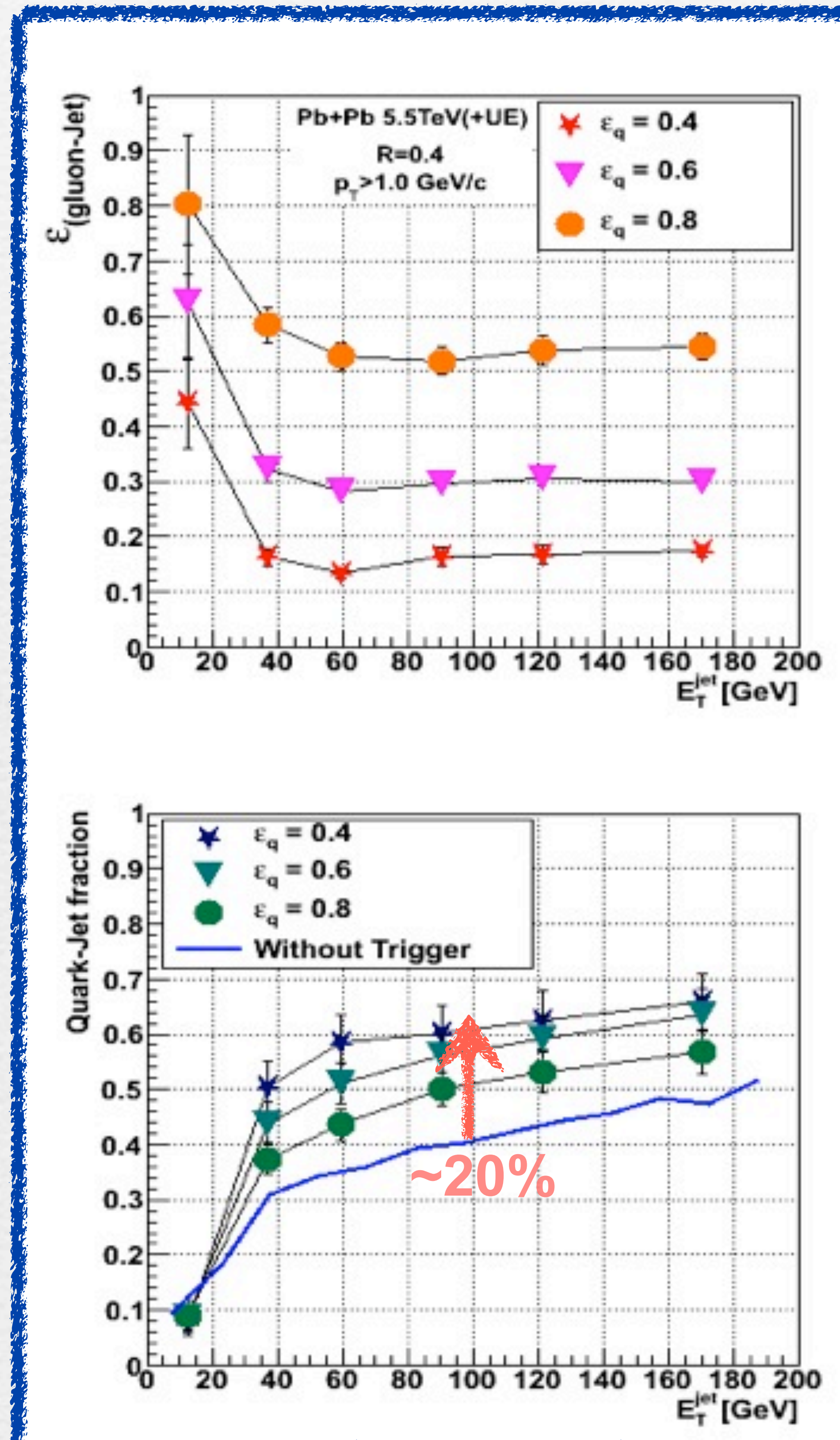
Quark/Gluon-Jetsの識別

Quark-Jet Trigger

p+p √s=14TeV(Pythia)



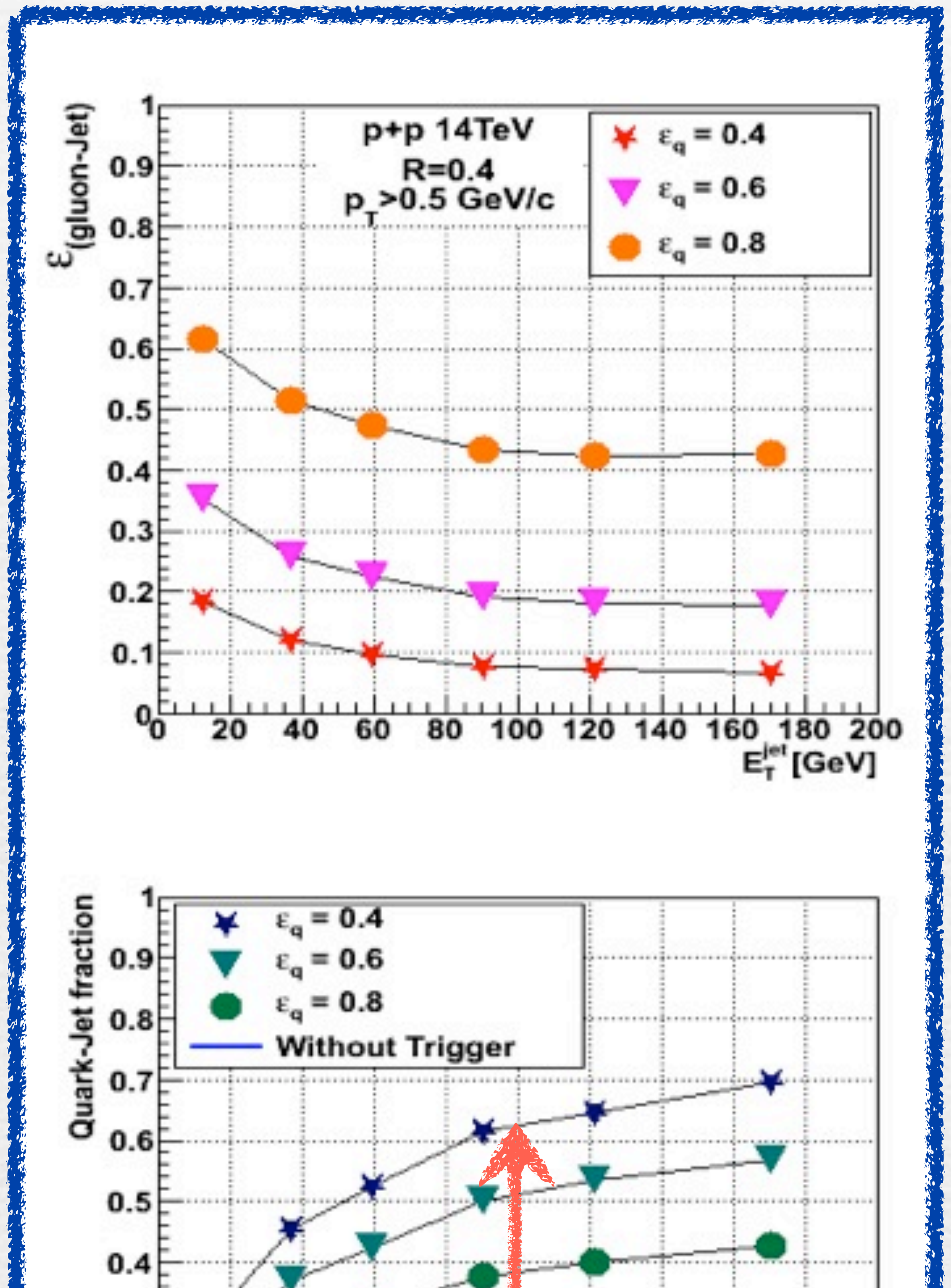
Pb+Pb $\sqrt{s_{NN}}$=5.5TeV(qPythia+HIJING)



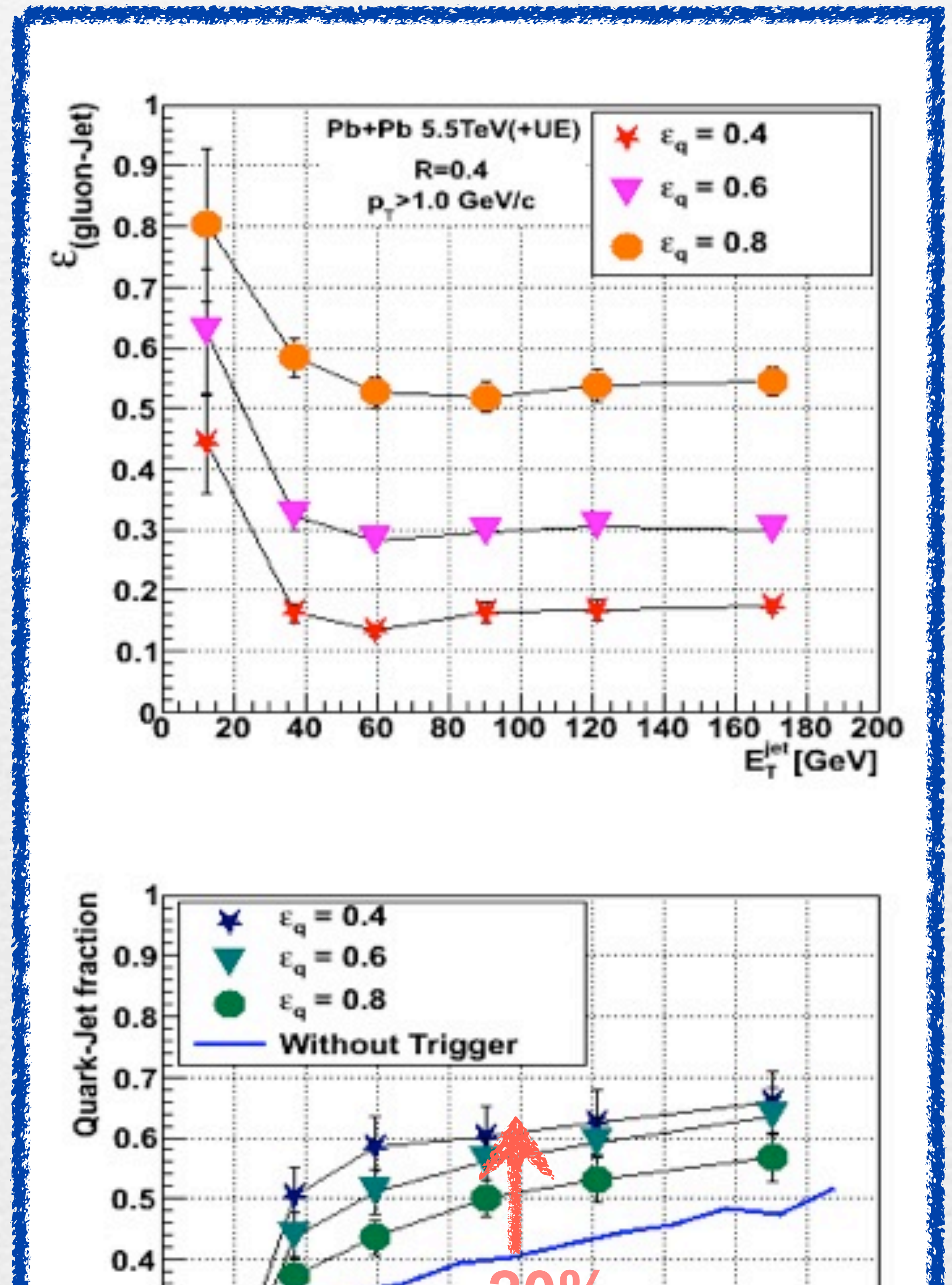
Quark/Gluon-Jetsの識別

Quark-Jet Trigger

p+p $\sqrt{s}$=14TeV(Pythia)



Pb+Pb $\sqrt{s_{NN}}$=5.5TeV(qPythia+HIJING)



識別後のジェット内のQuark-Jetの割合は ε_q によって変化する

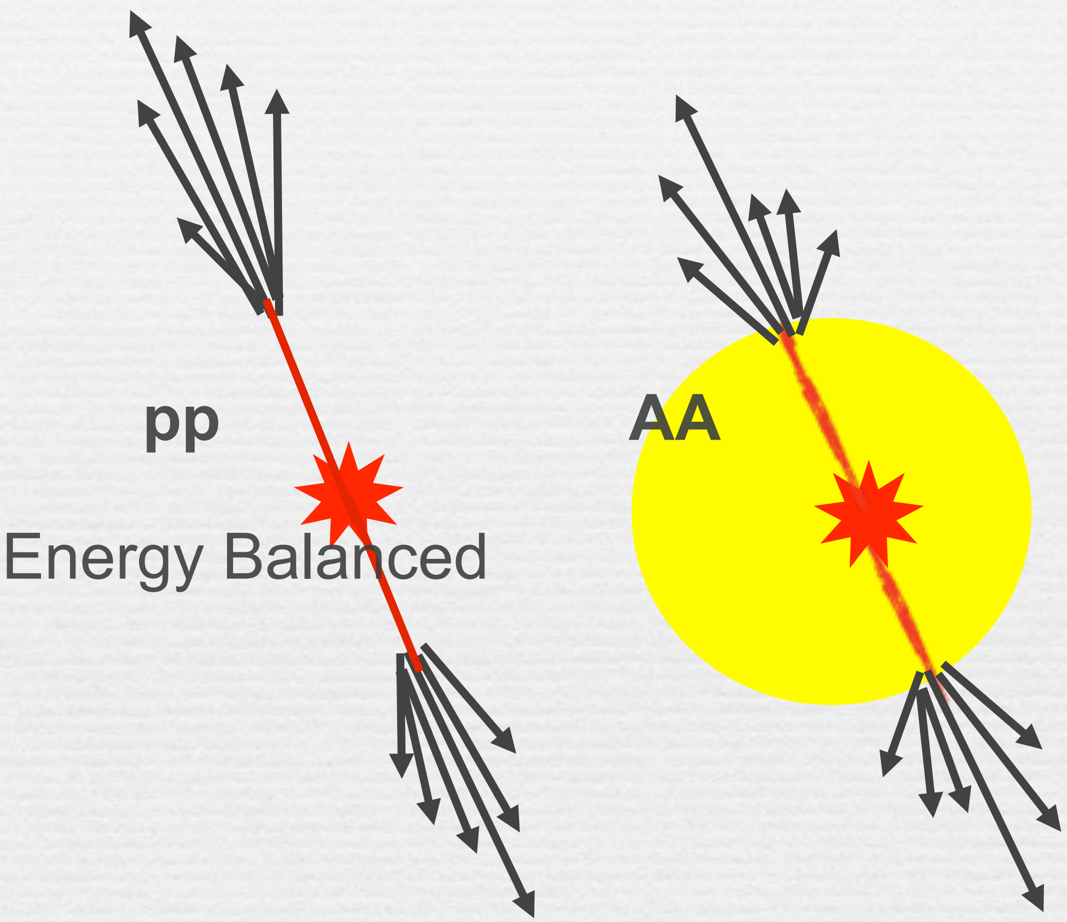
まとめと今後

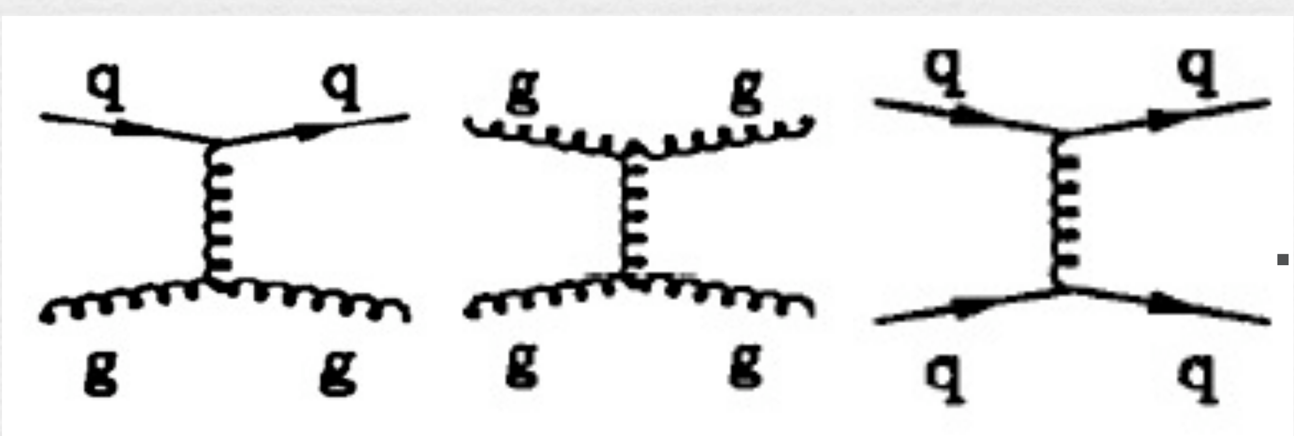
- まとめ:
  - Likelihood法を用いたQuark/Gluon-Jet識別
  - Quark-Jet識別効率によって識別されたジェット内のQuark-Jetの割合を変化させることが可能
    - ε_{quark}:1.0→0.4 $frac_{quark}$:~40% effect (p+p 14TeV)
    - ε_{quark}:1.0→0.4 $frac_{quark}$:~20% effect (Pb+Pb 5.5TeV)
- 今後:
  - Likelihood法で用いるパラメータの重み付け
  - NN法を用いたQuark/Gluon-Jet識別可能性の評価

backup

Di-Jet, γ-Jet

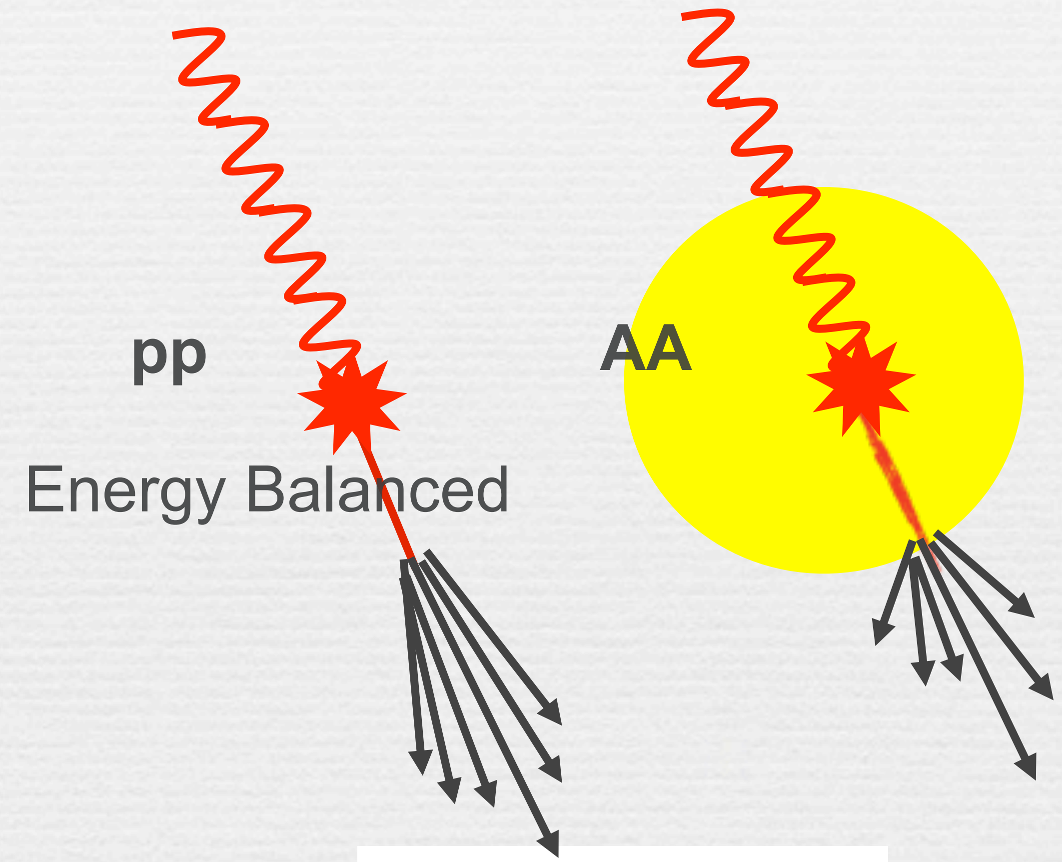
- **Di-Jets**
  - parton pair

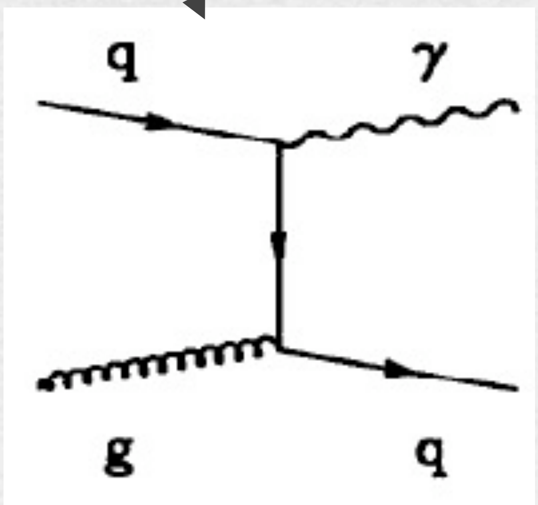




…

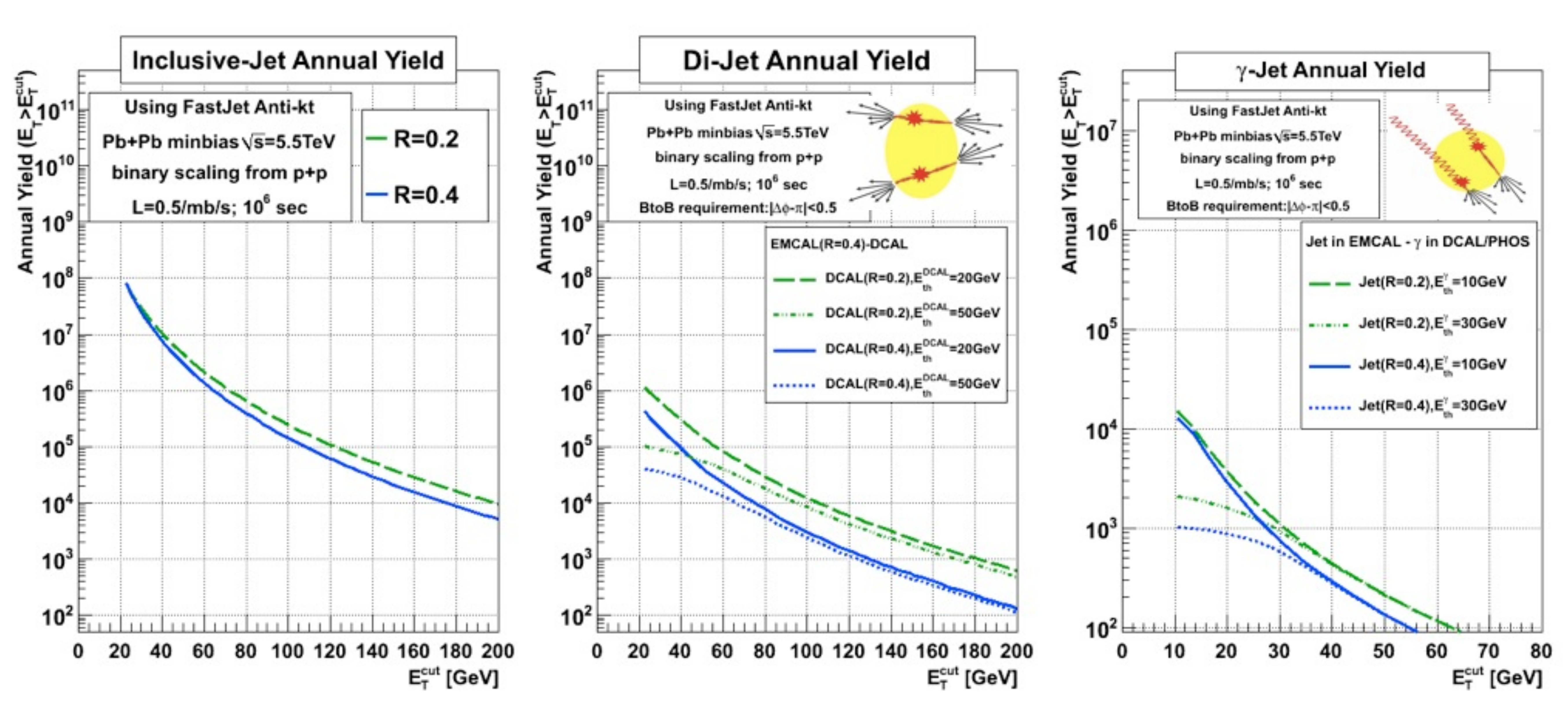
- **γ-Jets**
  - compton
  - γ-parton pair





Reach of Jet Energy at ALICE

- Inclusive-Jet, Di-Jet, γ-Jet Annual Yield at ALICE
  - 10^4 events/year for Jet Analysis
    - Inclusive-Jet : ~200GeV
    - Di-Jet : ~100GeV



fastjet anti-kt algorithm

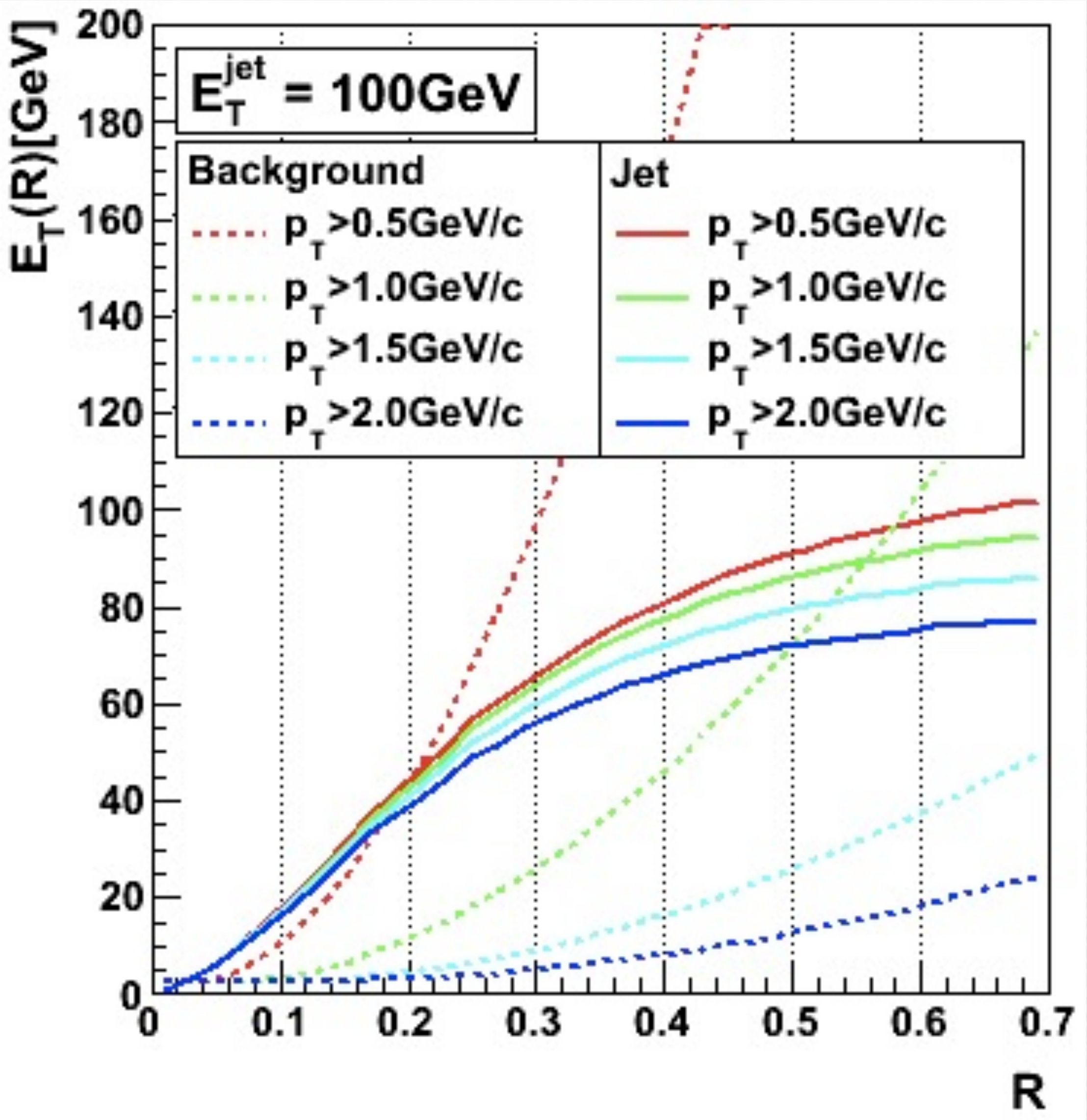
- FastJet-anti-kt algorithm
  - (http://www.lpthe.jussieu.fr/~salam/fastjet/)

1. calculate d_{ij} and d_{iB} by all particles combination
2. when minimum “d” among them is part of d_{ij}
   - merge particle “i” and “j”
3. when minimum “d” among them is part of d_{iB}
   - that cluster defined as jet
4. repeat until no particle are left

$$d_{ij} = \min(1/k_{ti}^2, 1/k_{tj}^2)\,\Delta R_{ij}^2/R^2\,,$$
$$d_{iB} = 1/k_{ti}^2\,.$$

Heavy Ion Background

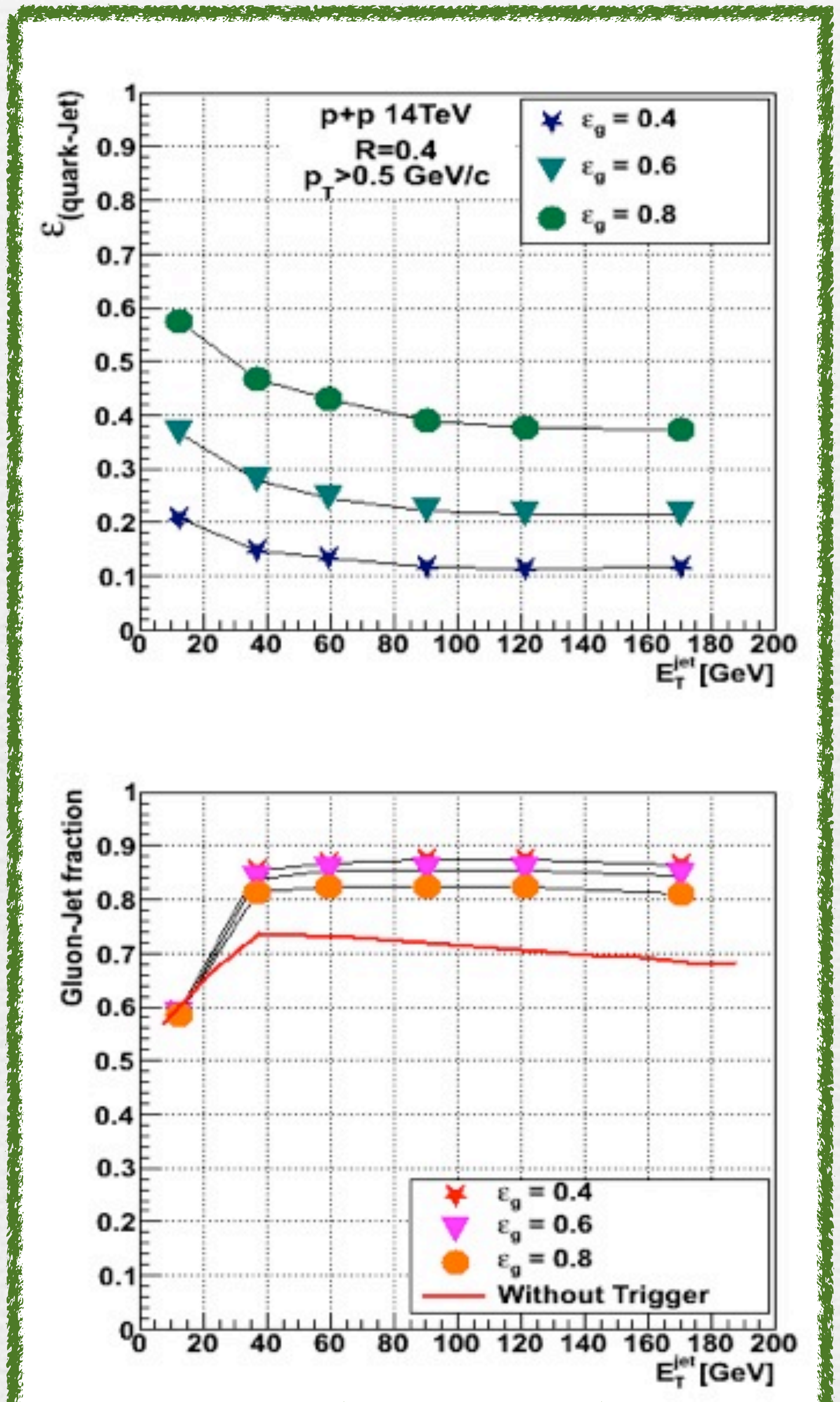
- A lot of particles from minijets & QGP
  - →Background for high energy jets
- BKG is increase as jet-radius parameter : R
- Particle p_T-cut for subtract BKG



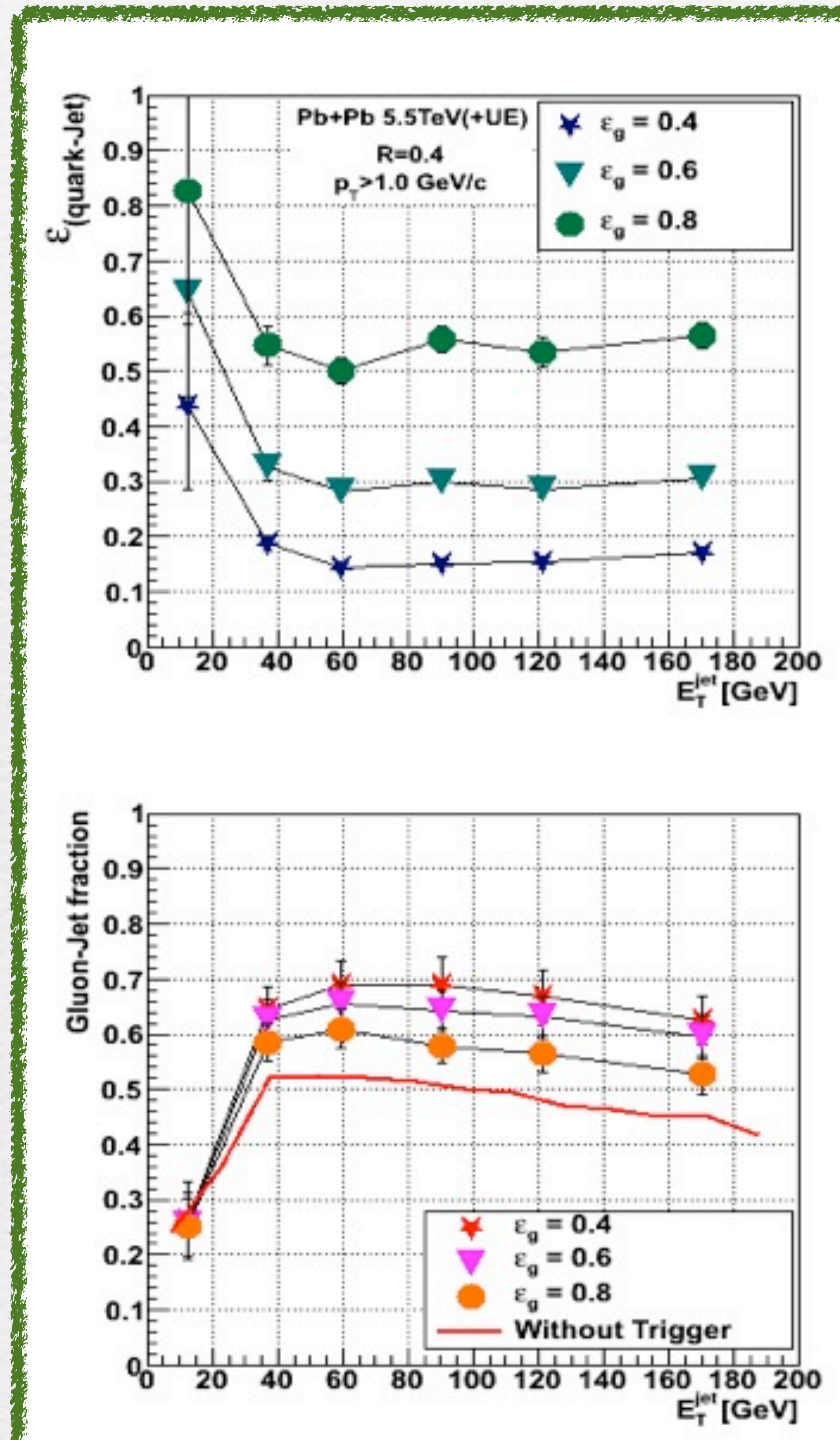
Separation of Quark/Gluon-Jets

Gluon-Jet Trigger

p+p √s=14TeV(Pythia)



Pb+Pb √sNN=5.5TeV(qPythia+HIJING)

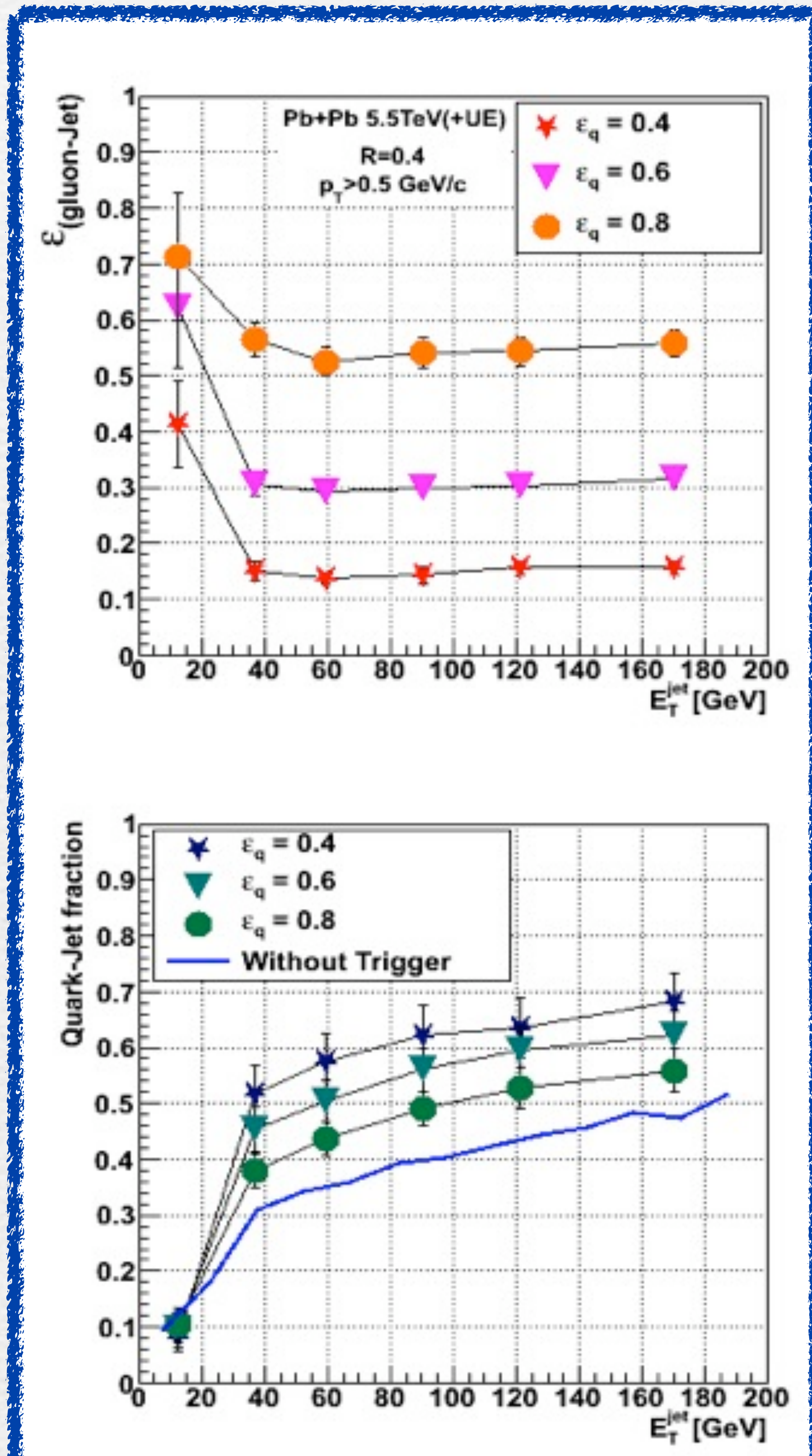


pTcut dependence

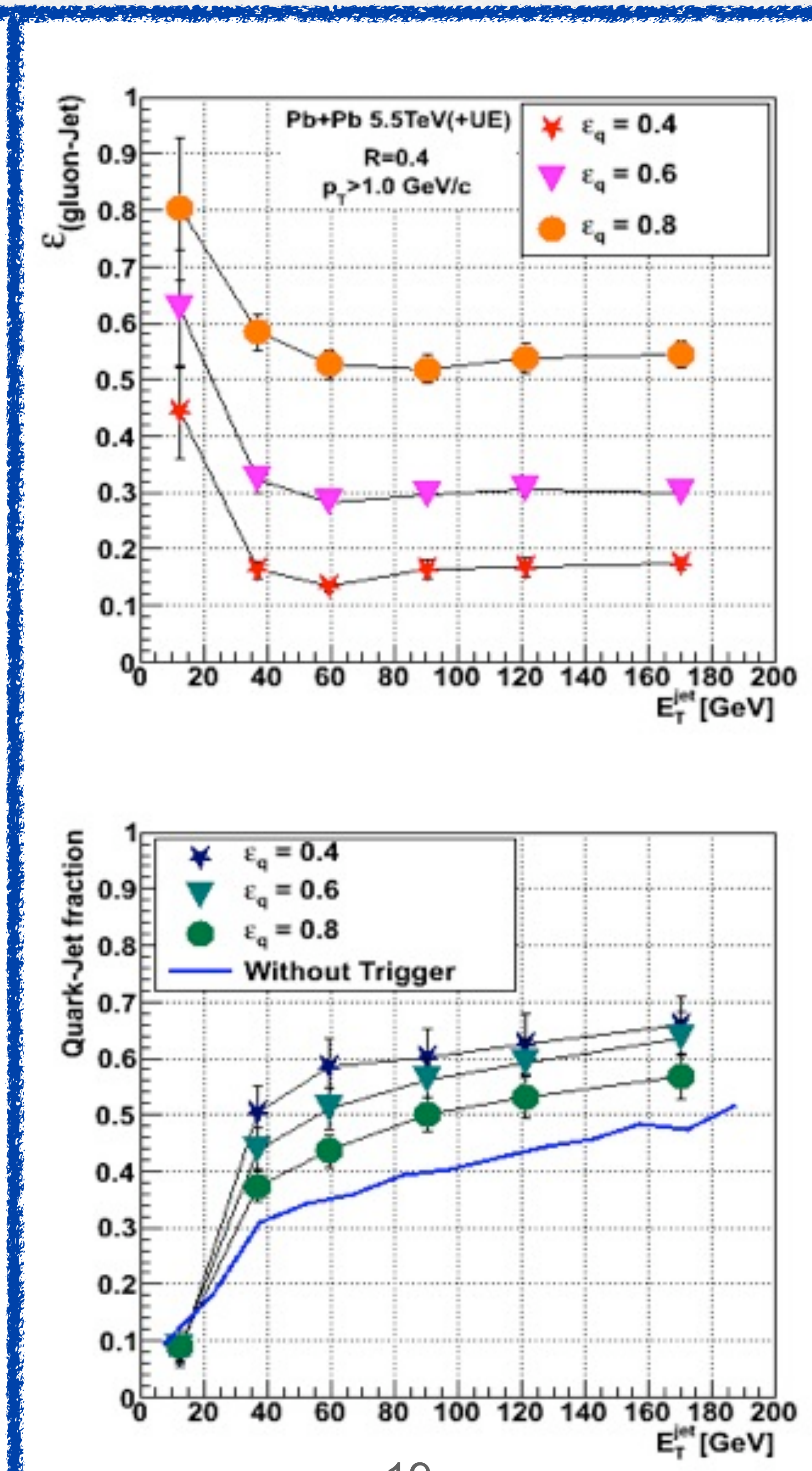
Quark-Jet Trigger

Pb+Pb $\sqrt{s_{NN}}$=5.5TeV (qPythia+HIJING)

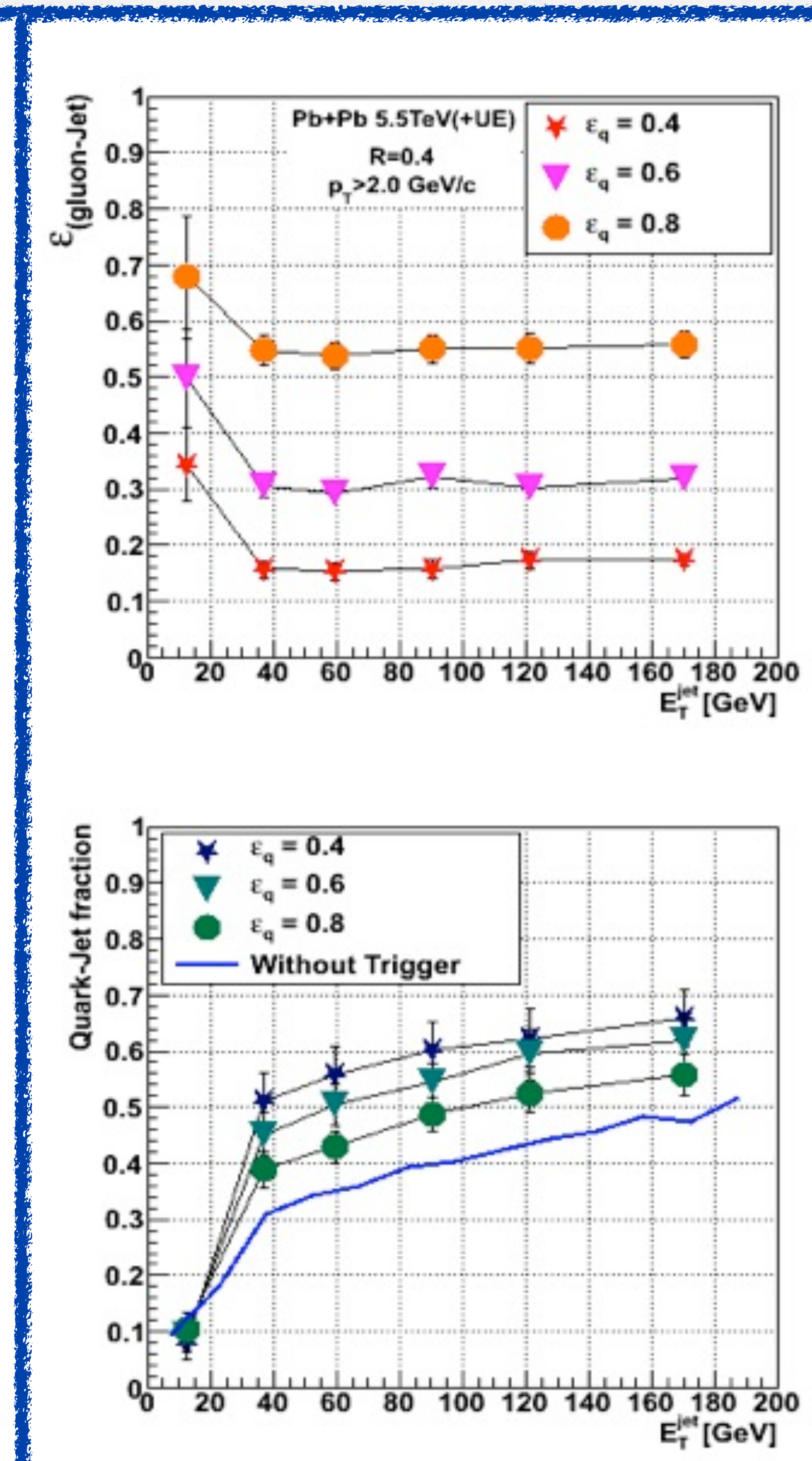
p_T>0.5GeV/c



p_T>1.0GeV/c



p_T>2.0GeV/c

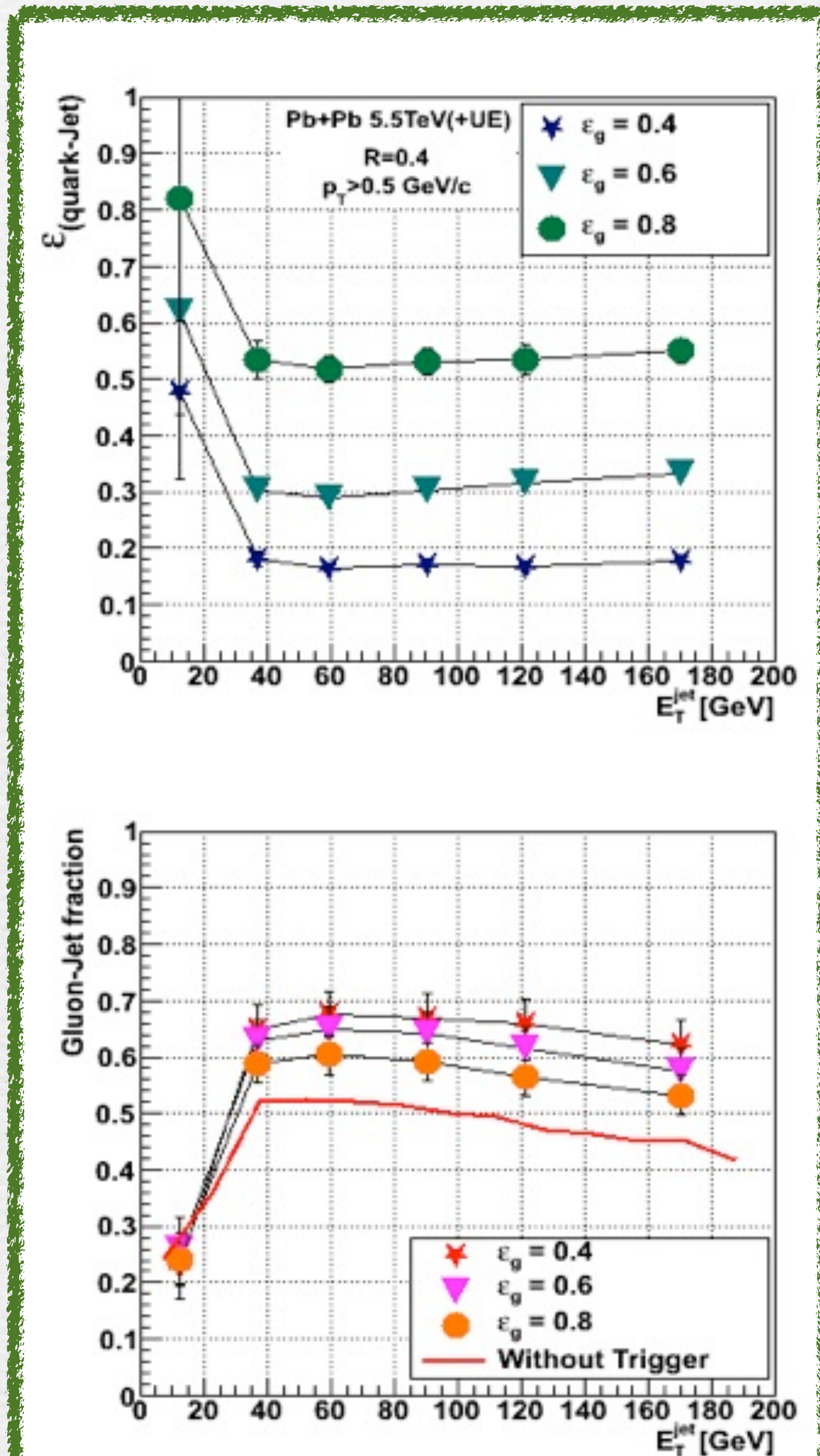


pTcut dependence

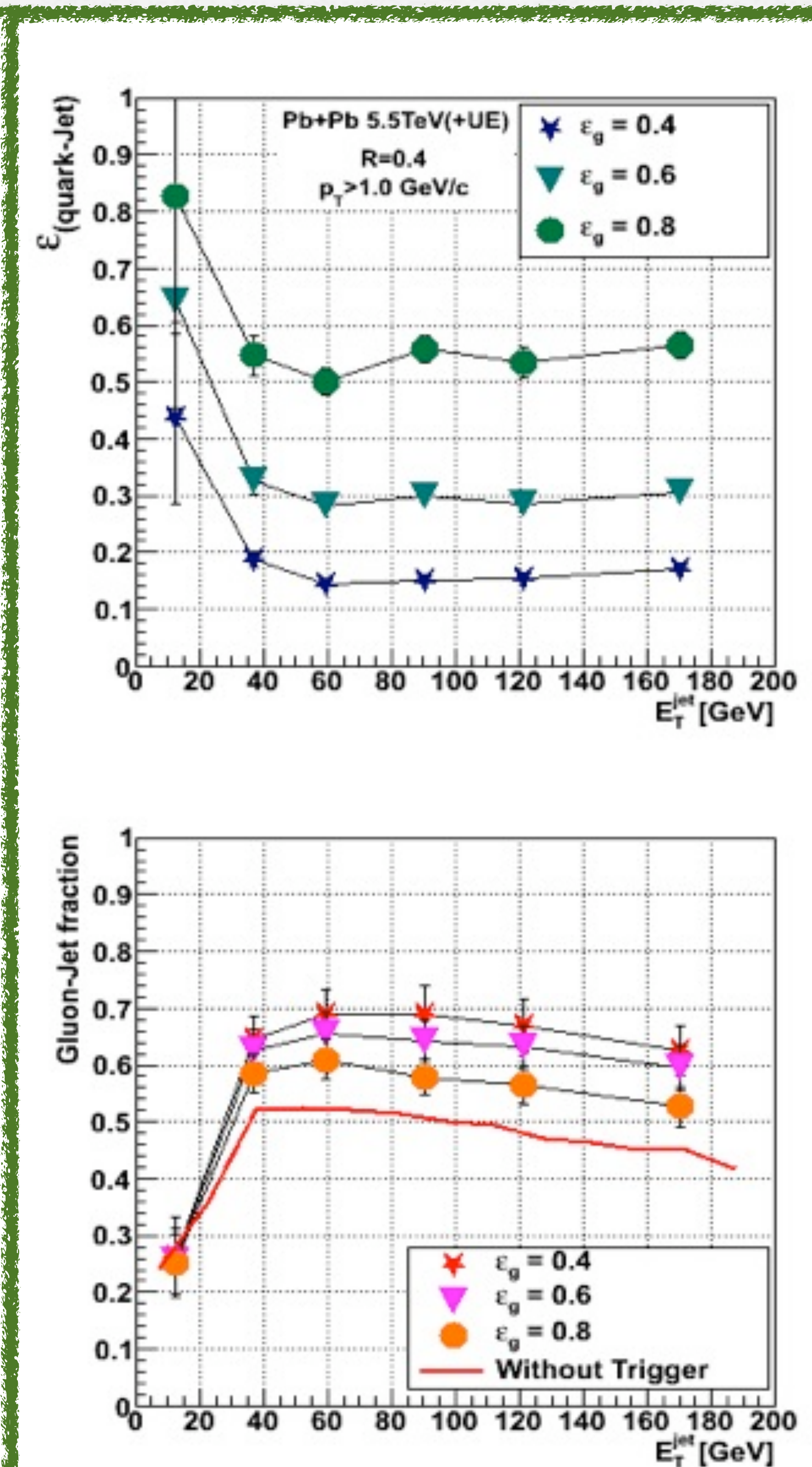
Gluon-Jet Trigger

Pb+Pb $\sqrt{s_{NN}}$=5.5TeV
(qPythia+HIJING)

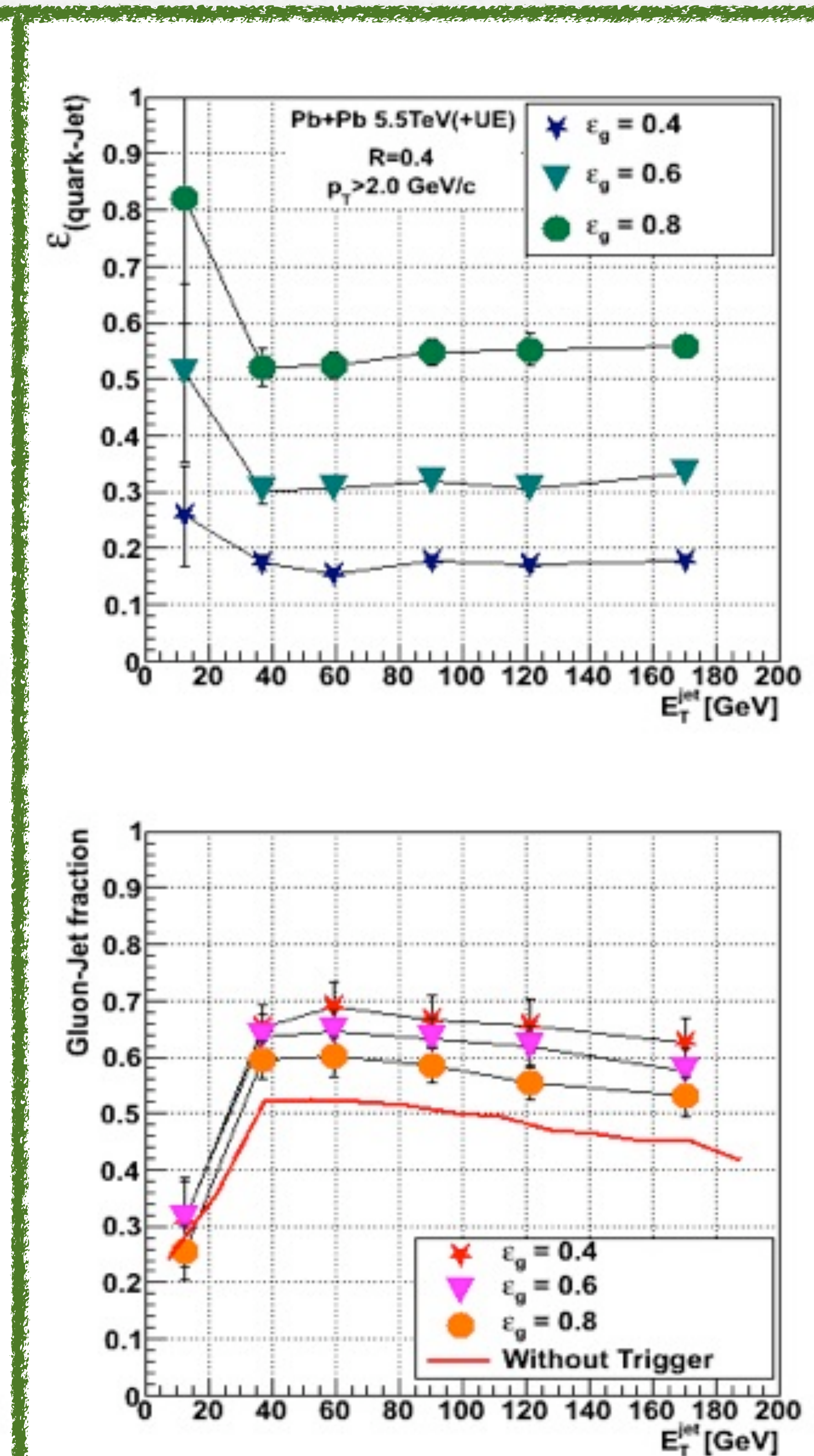
p_T>0.5GeV/c



p_T>1.0GeV/c



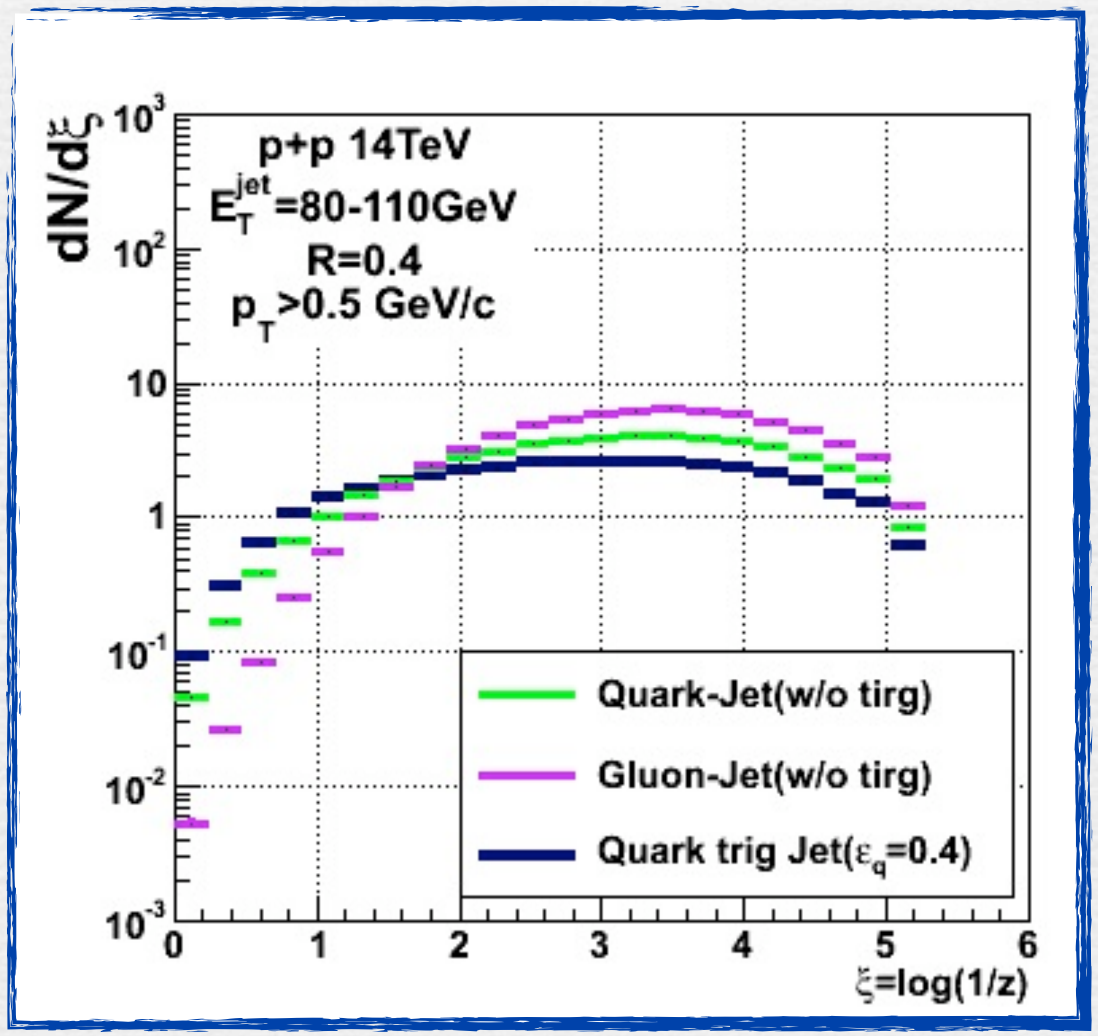
p_T>2.0GeV/c



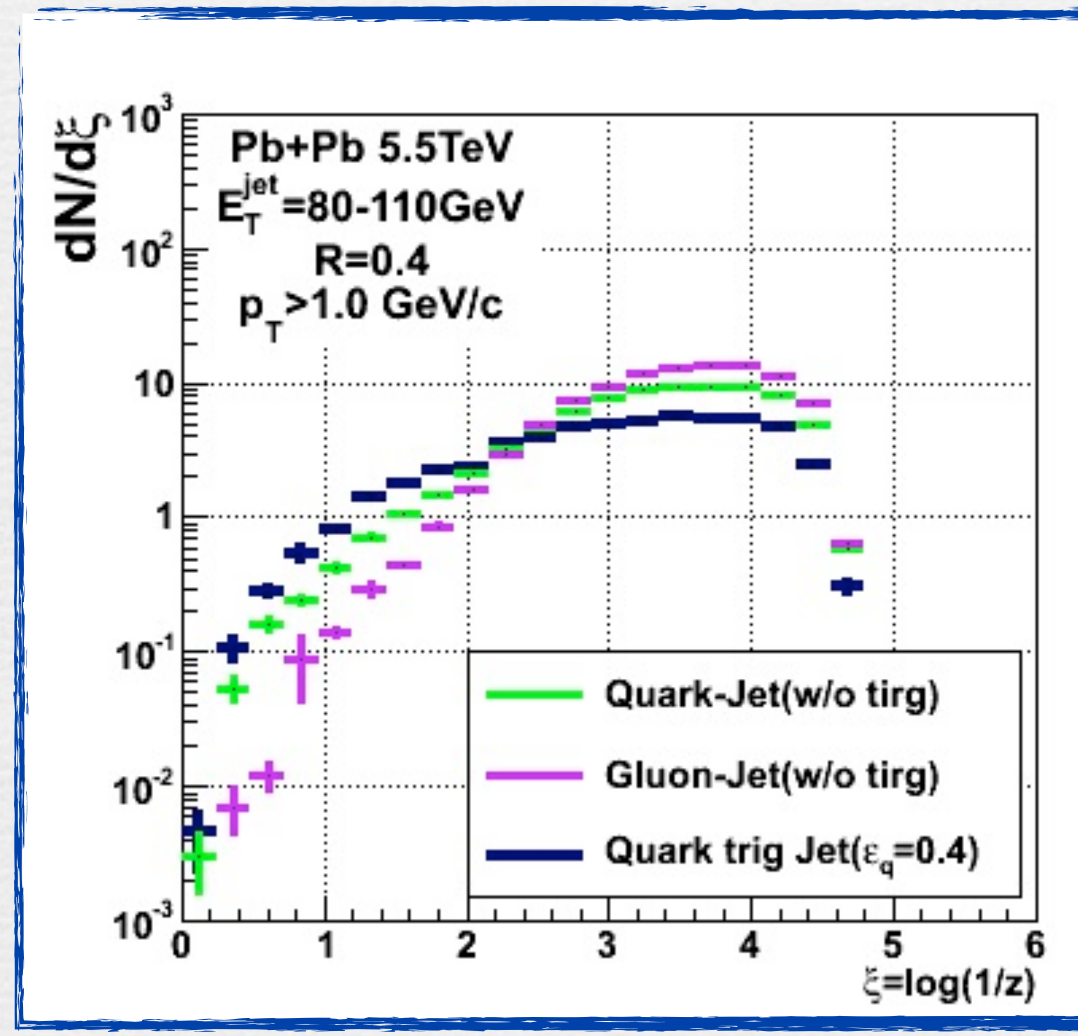
Fragmentation Function

Quark-Jet Trigger (ε_q=0.4)

p+p $\sqrt{s}$=14TeV(Pythia)



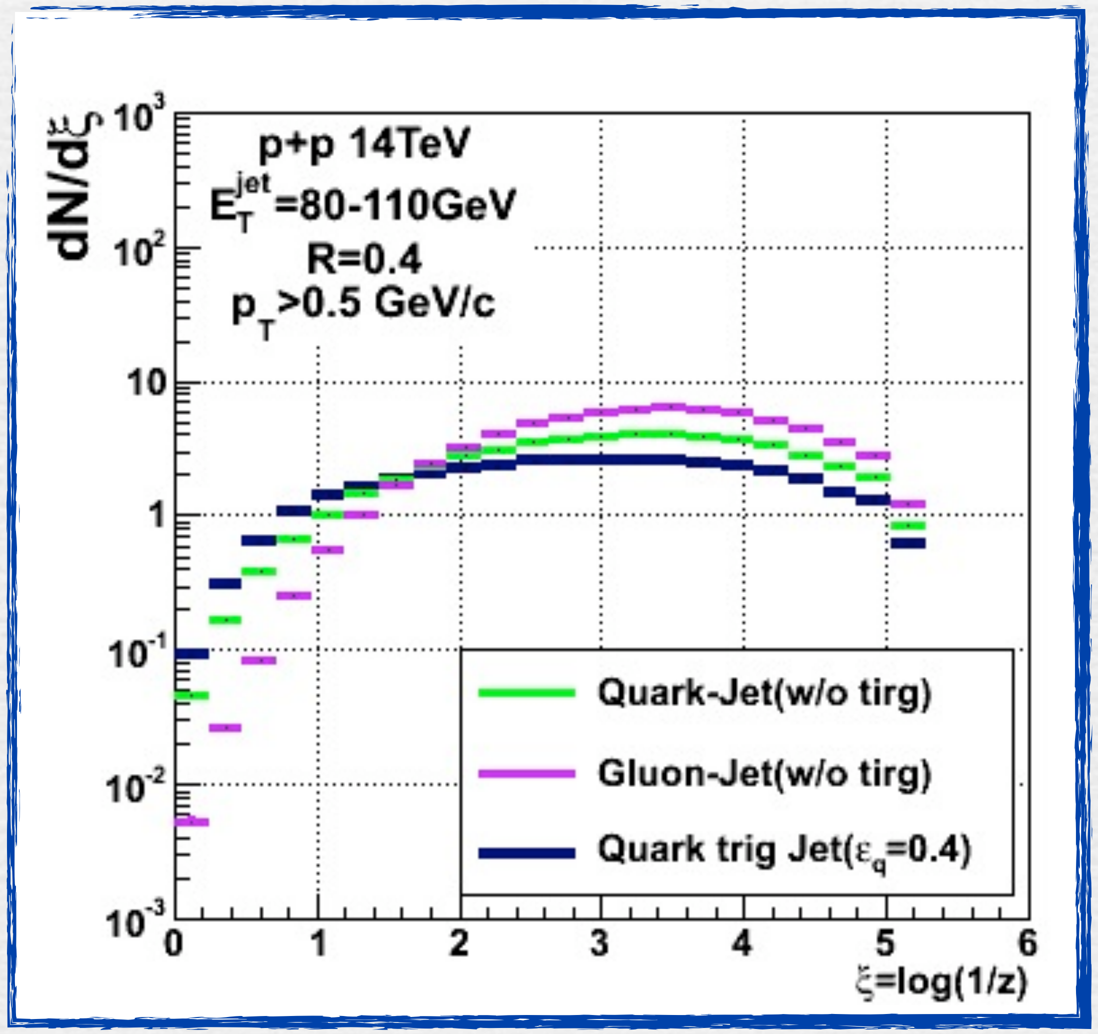
Pb+Pb $\sqrt{s_{NN}}$=5.5TeV(qPythia+HIJING)



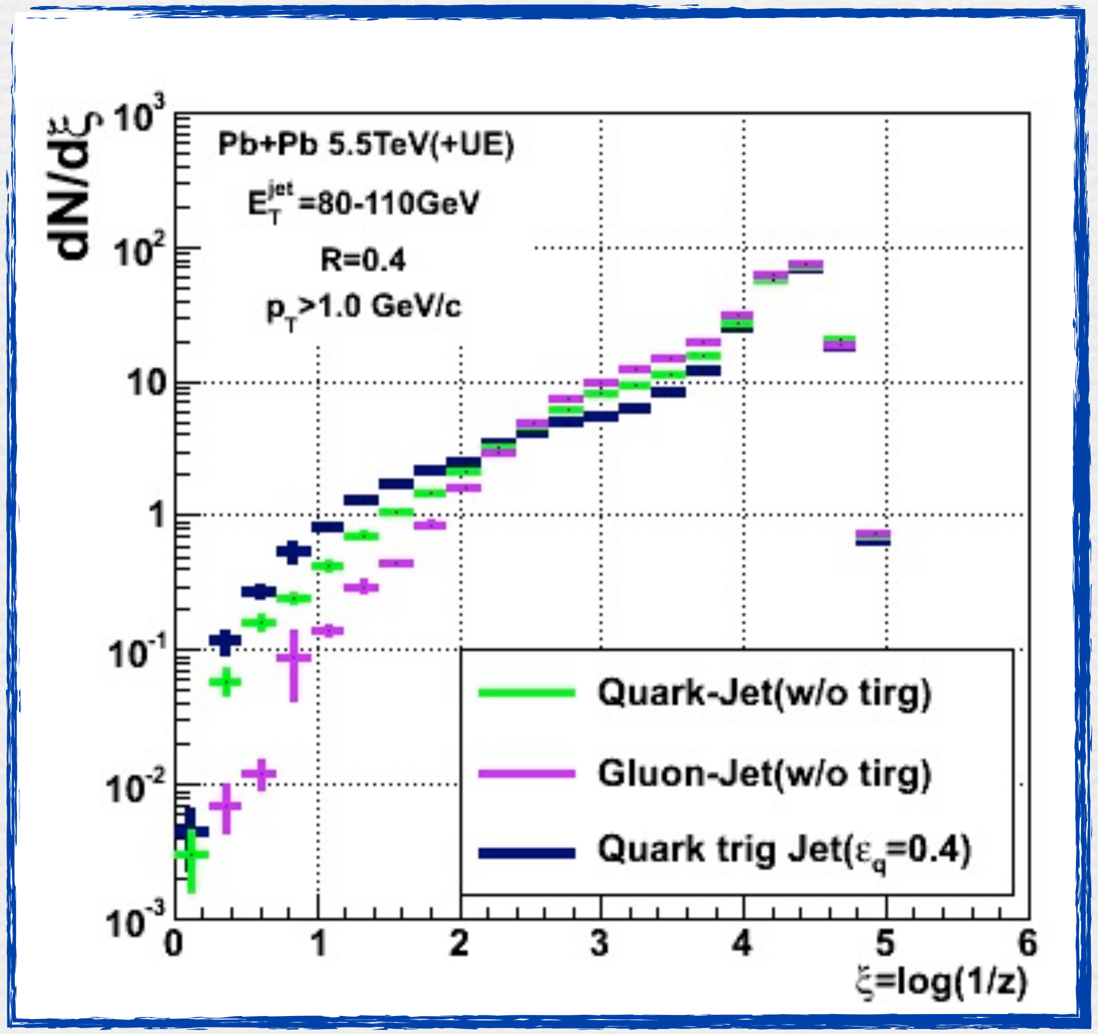
Fragmentation Function

Quark-Jet Trigger (ε_q=0.4)

p+p $\sqrt{s}$=14TeV(Pythia)



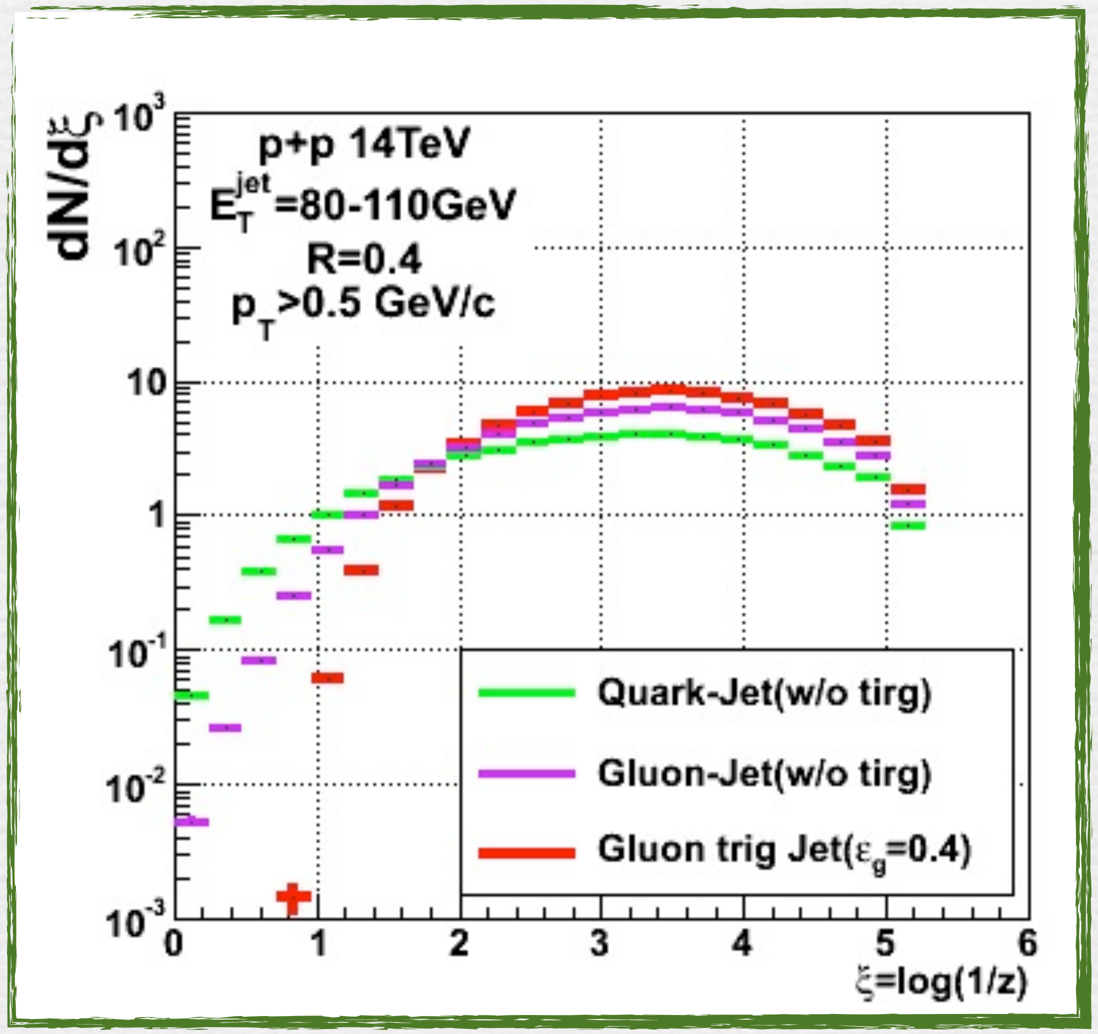
Pb+Pb $\sqrt{s_{NN}}$=5.5TeV(qPythia+HIJING)



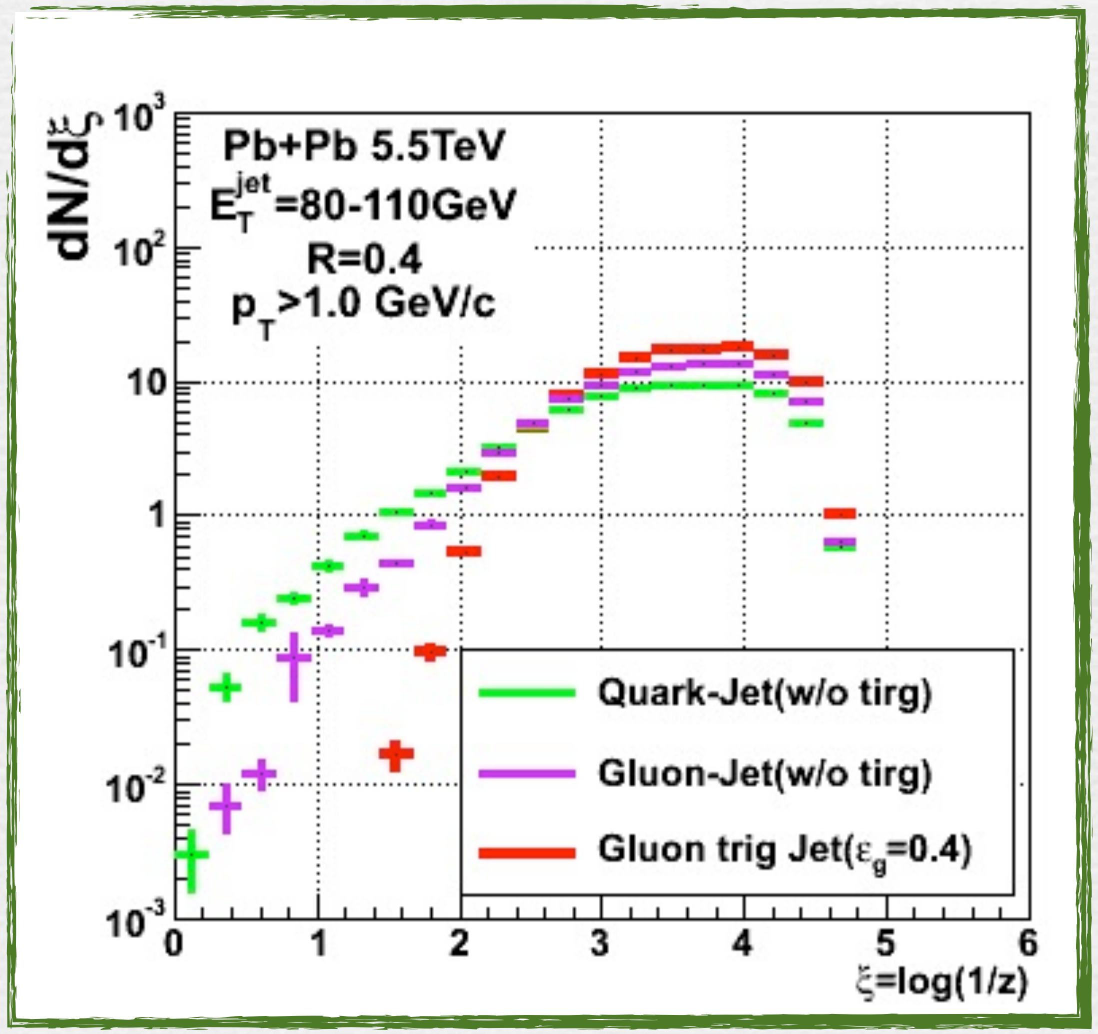
Fragmentation Function

Gluon-Jet Trigger (ε_g=0.4)

p+p $\sqrt{s}$=14TeV(Pythia)



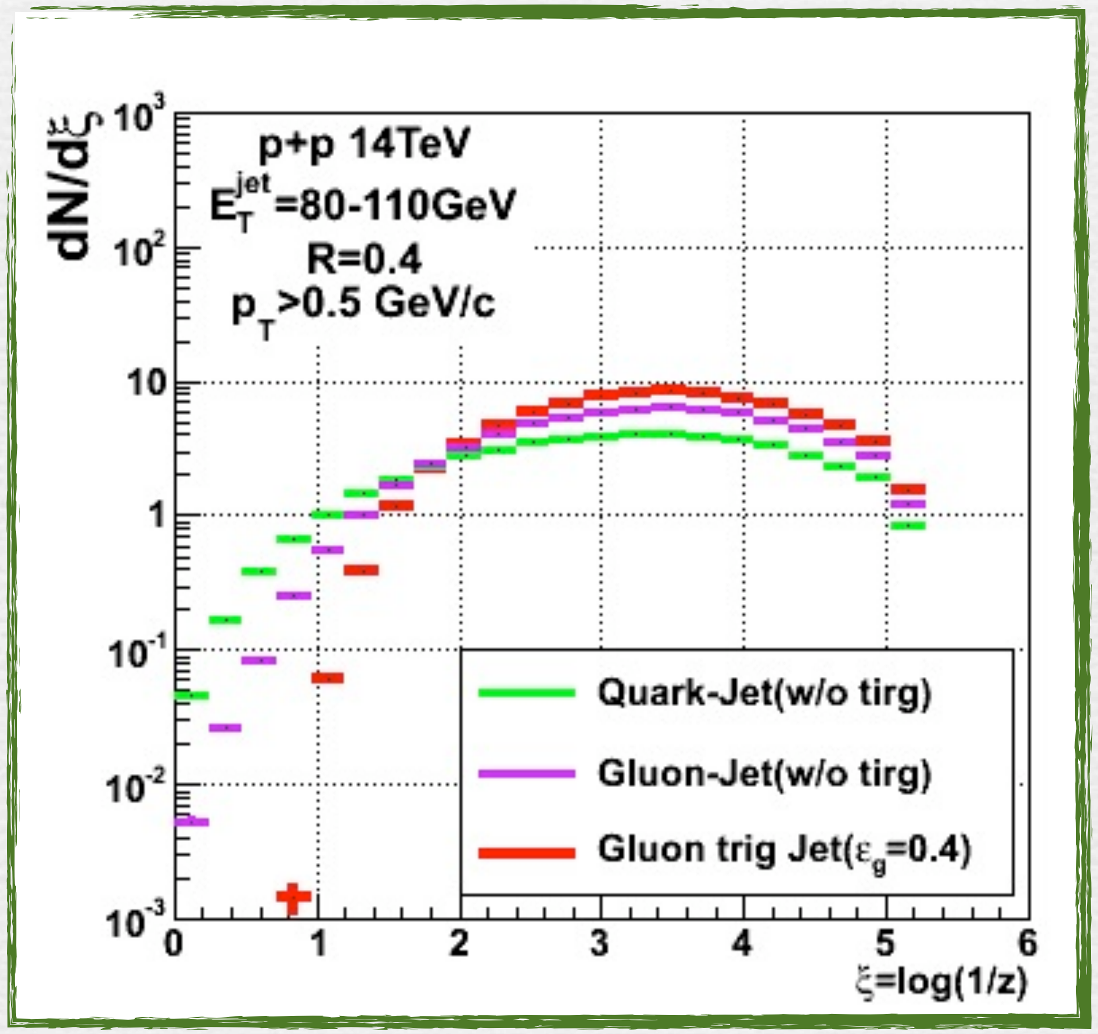
Pb+Pb $\sqrt{s_{NN}}$=5.5TeV(qPythia+HIJING)



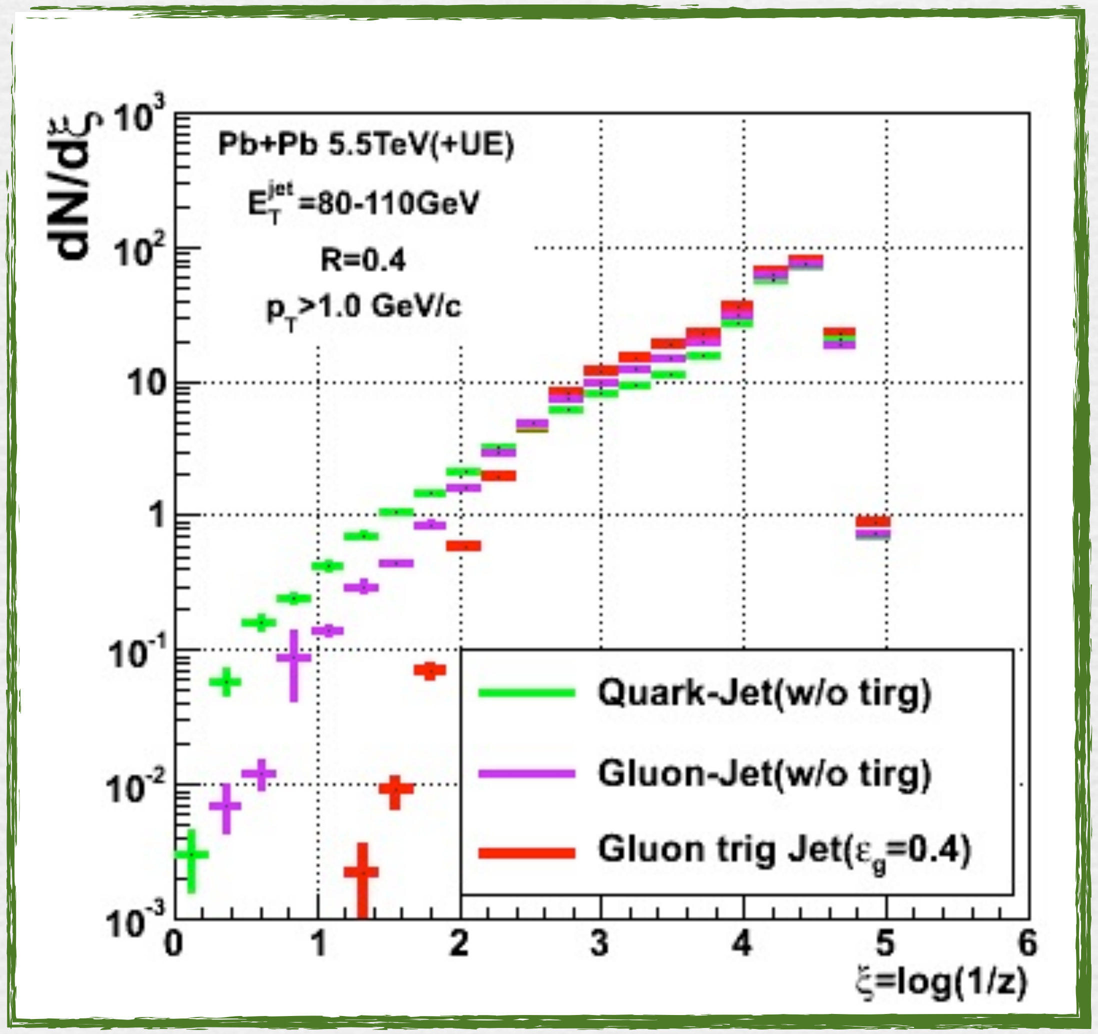
Fragmentation Function

Gluon-Jet Trigger (ε_g=0.4)

p+p √s=14TeV(Pythia)

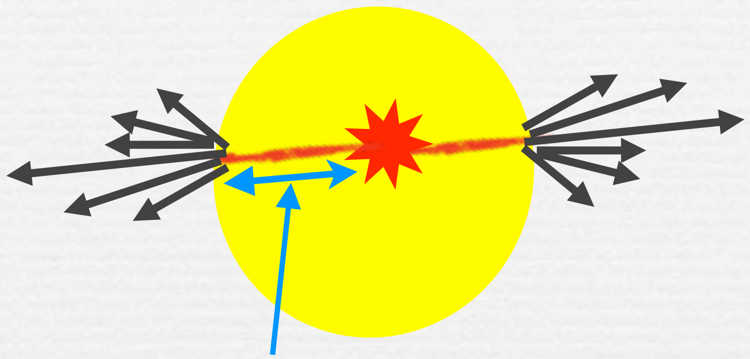


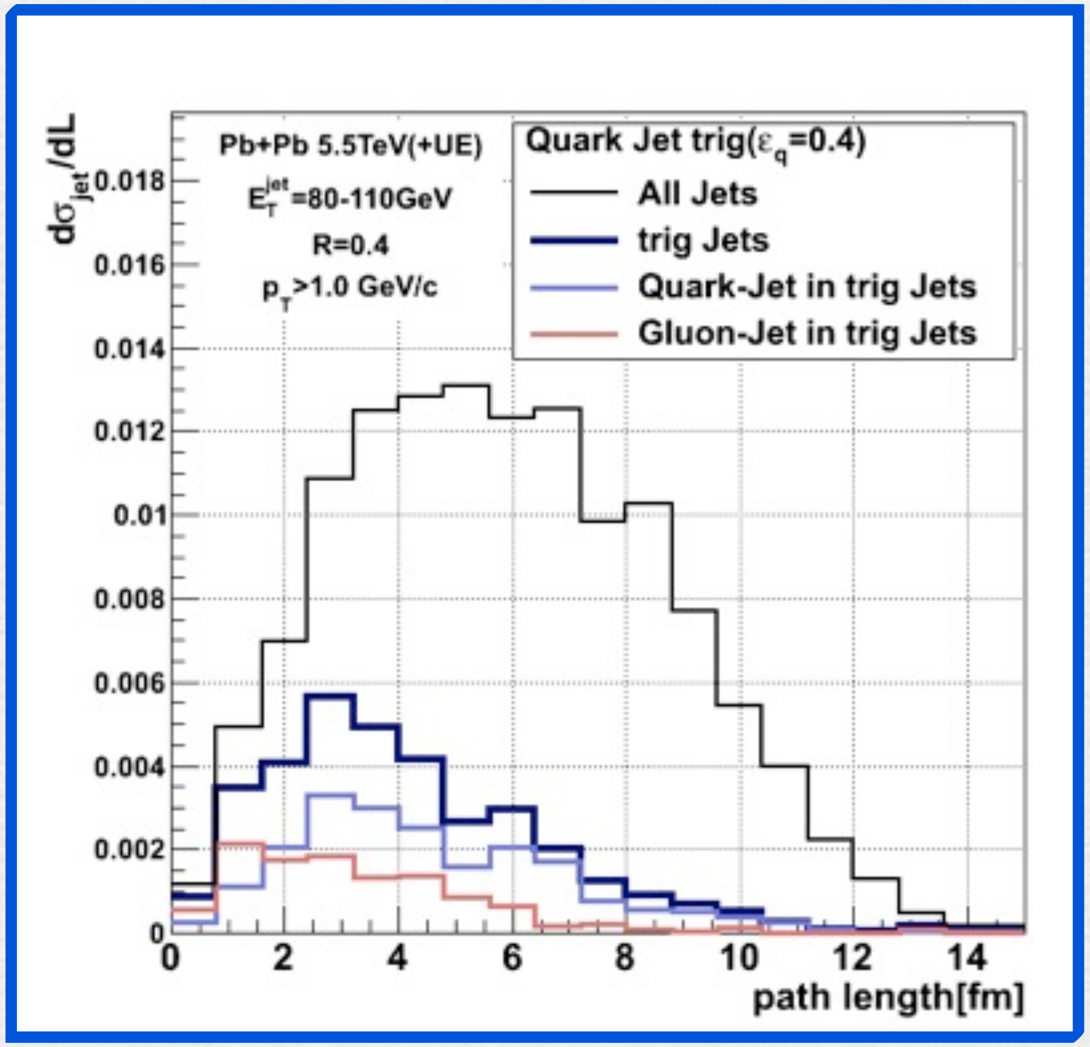
Pb+Pb $\sqrt{s_{NN}}$=5.5TeV(qPythia+HIJING)

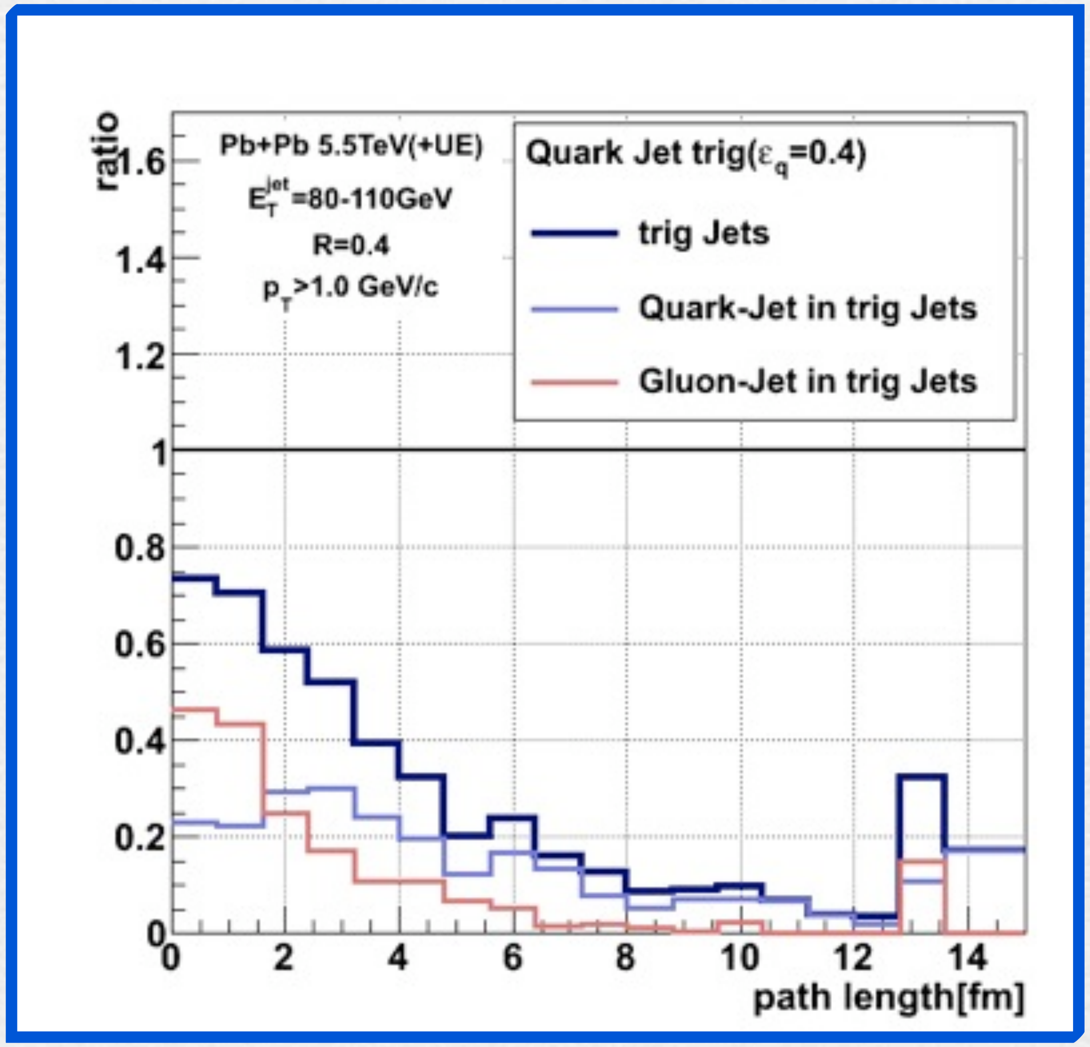


Surface Bias

Quark-Jet Trigger (ε_q=0.4)

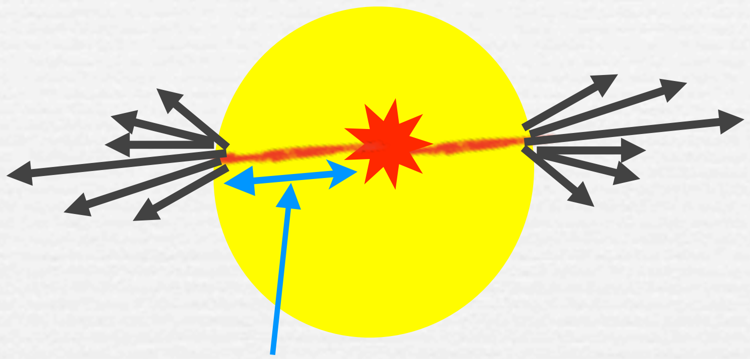


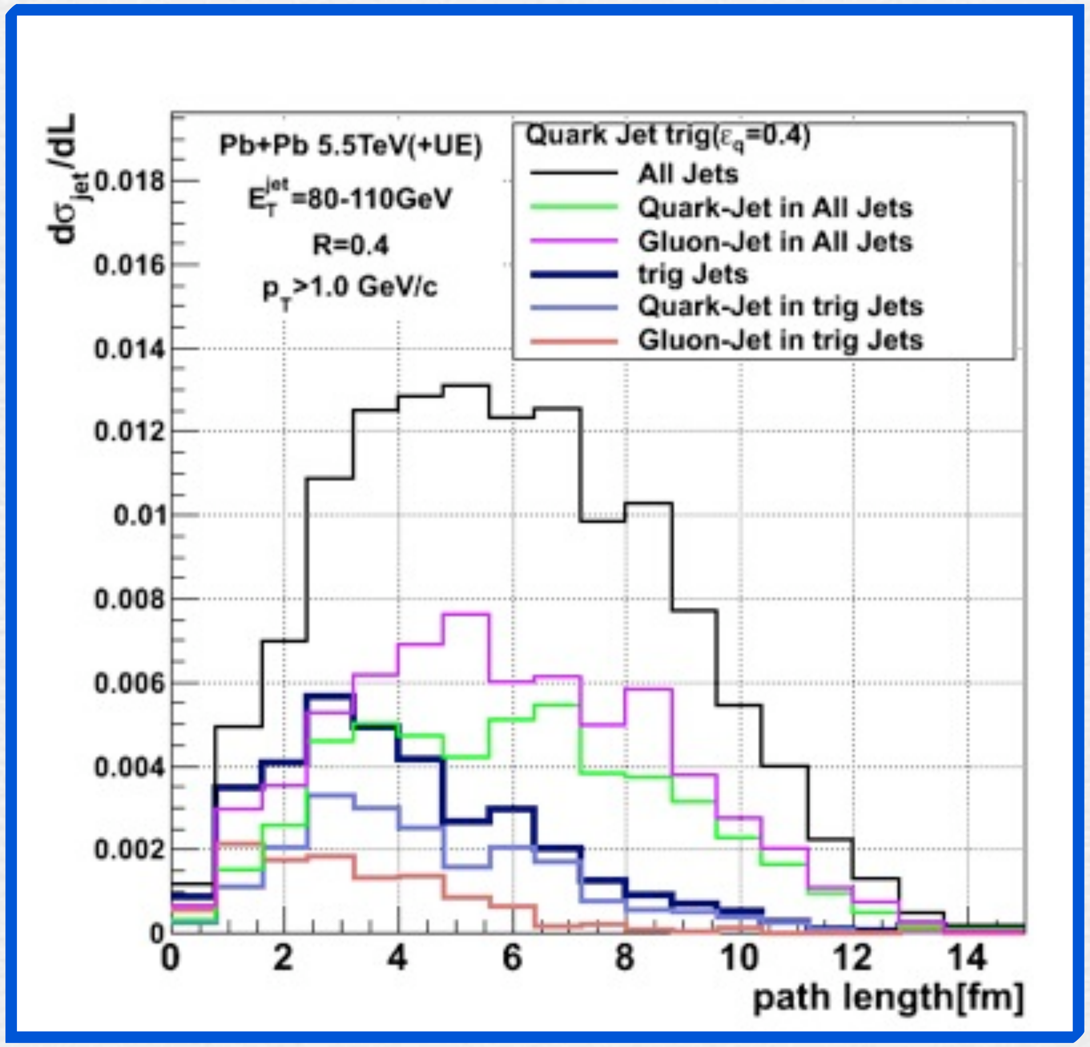


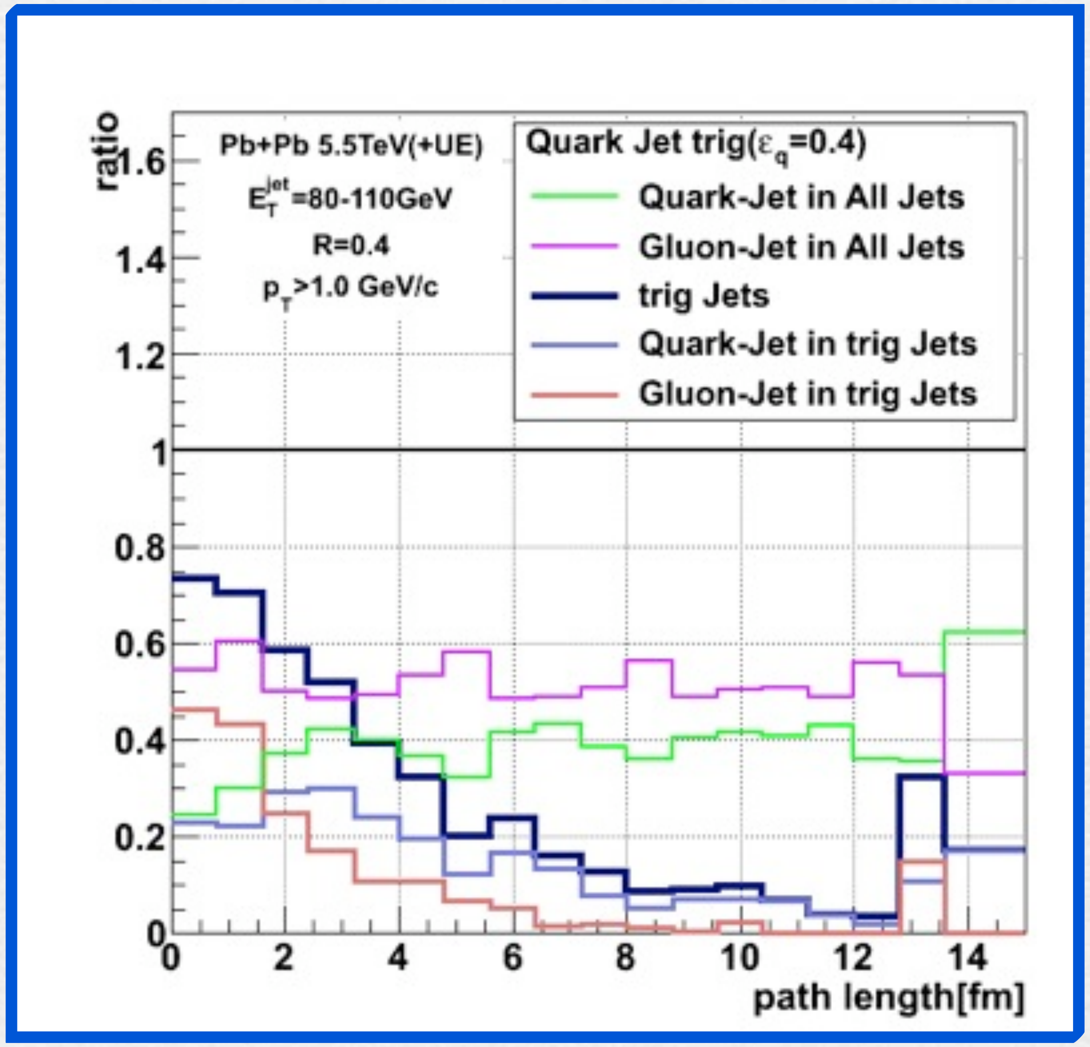


Surface Bias

Quark-Jet Trigger (ε_q=0.4)

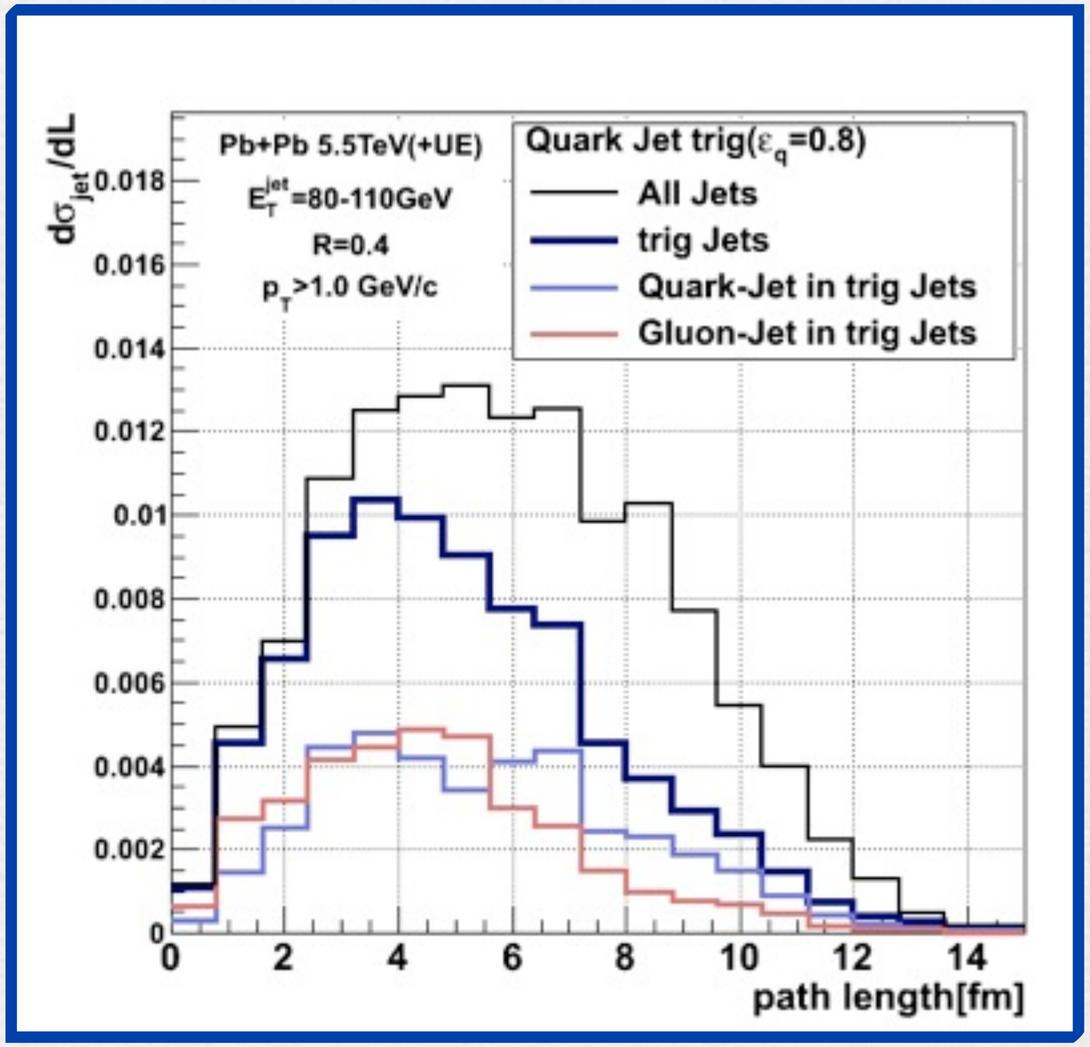


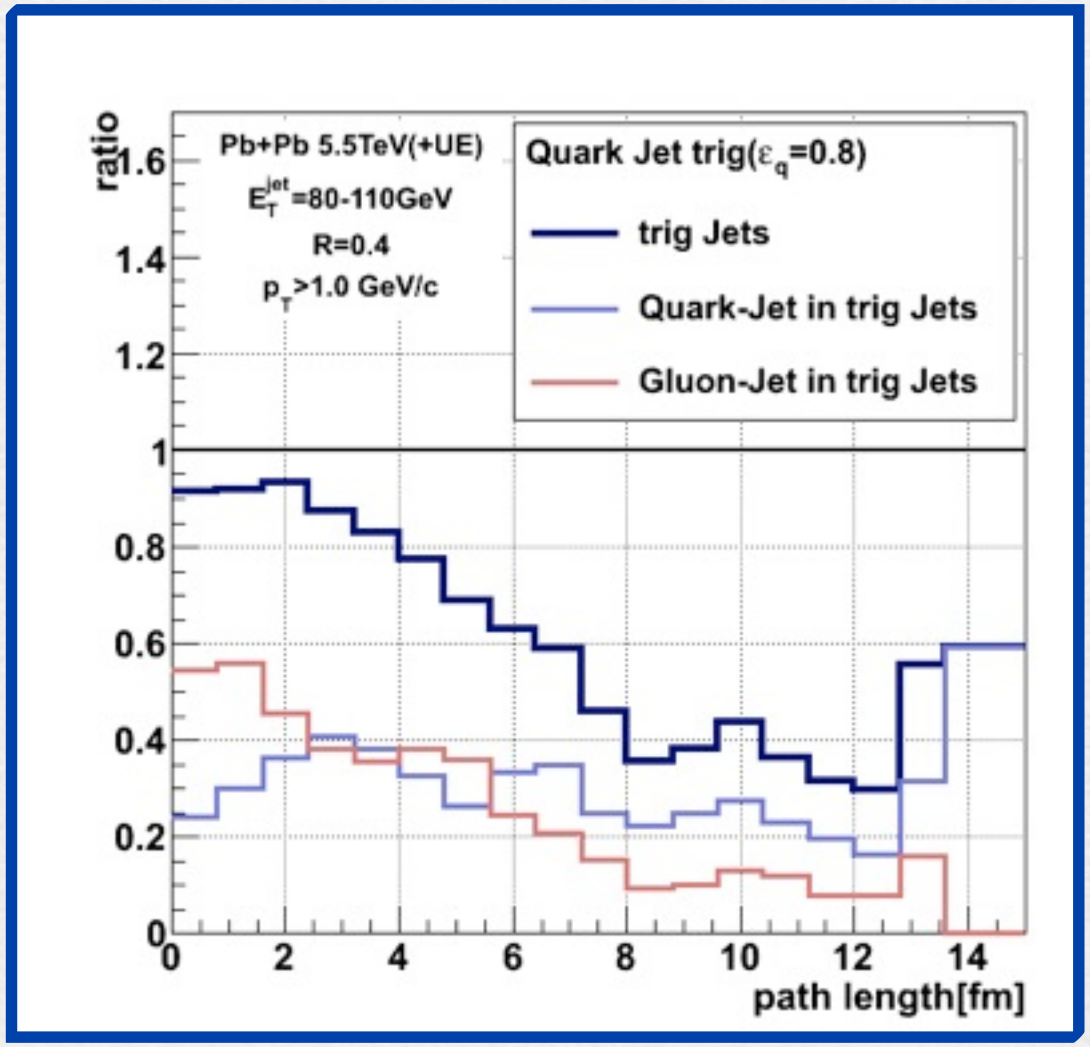




Surface Bias

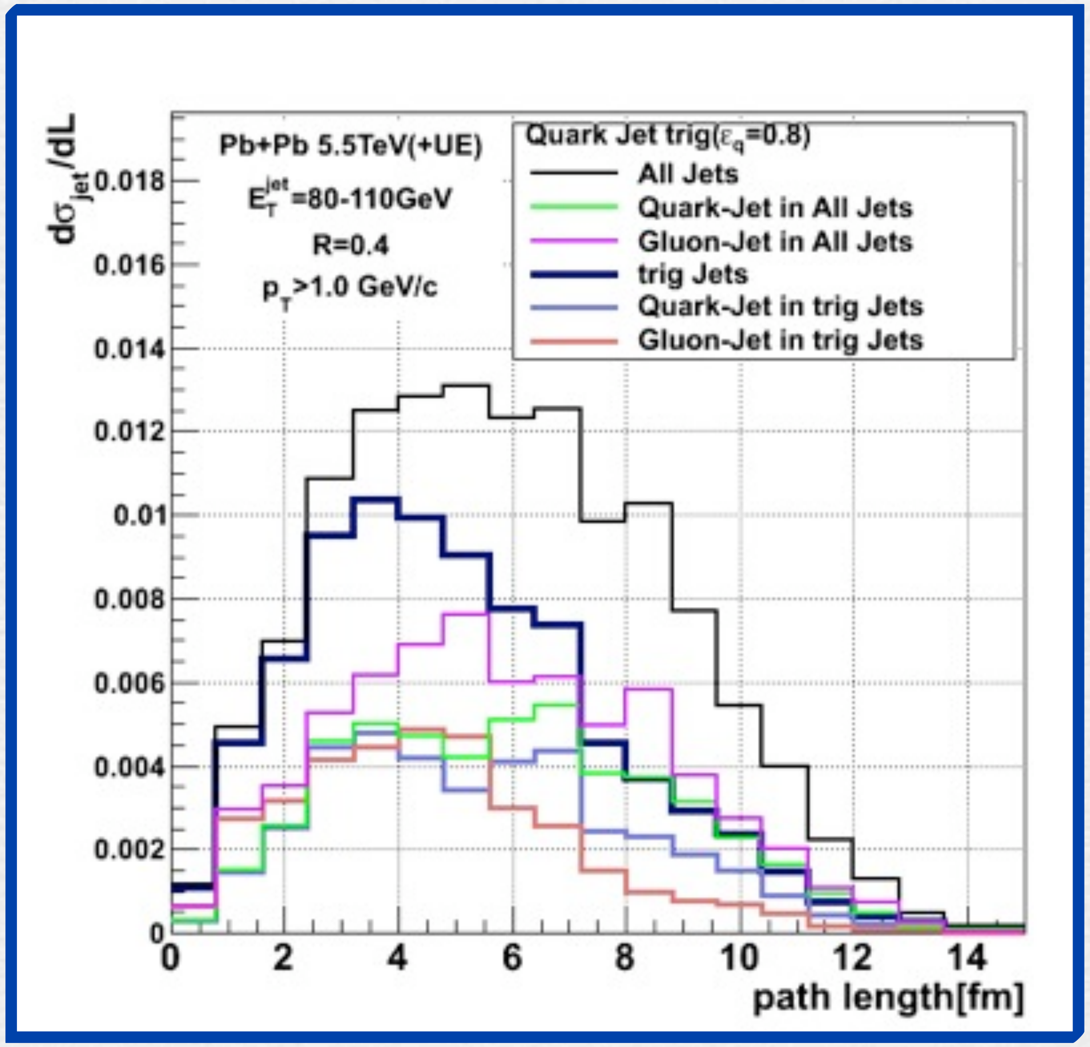
Quark-Jet Trigger (ε_q=0.8)

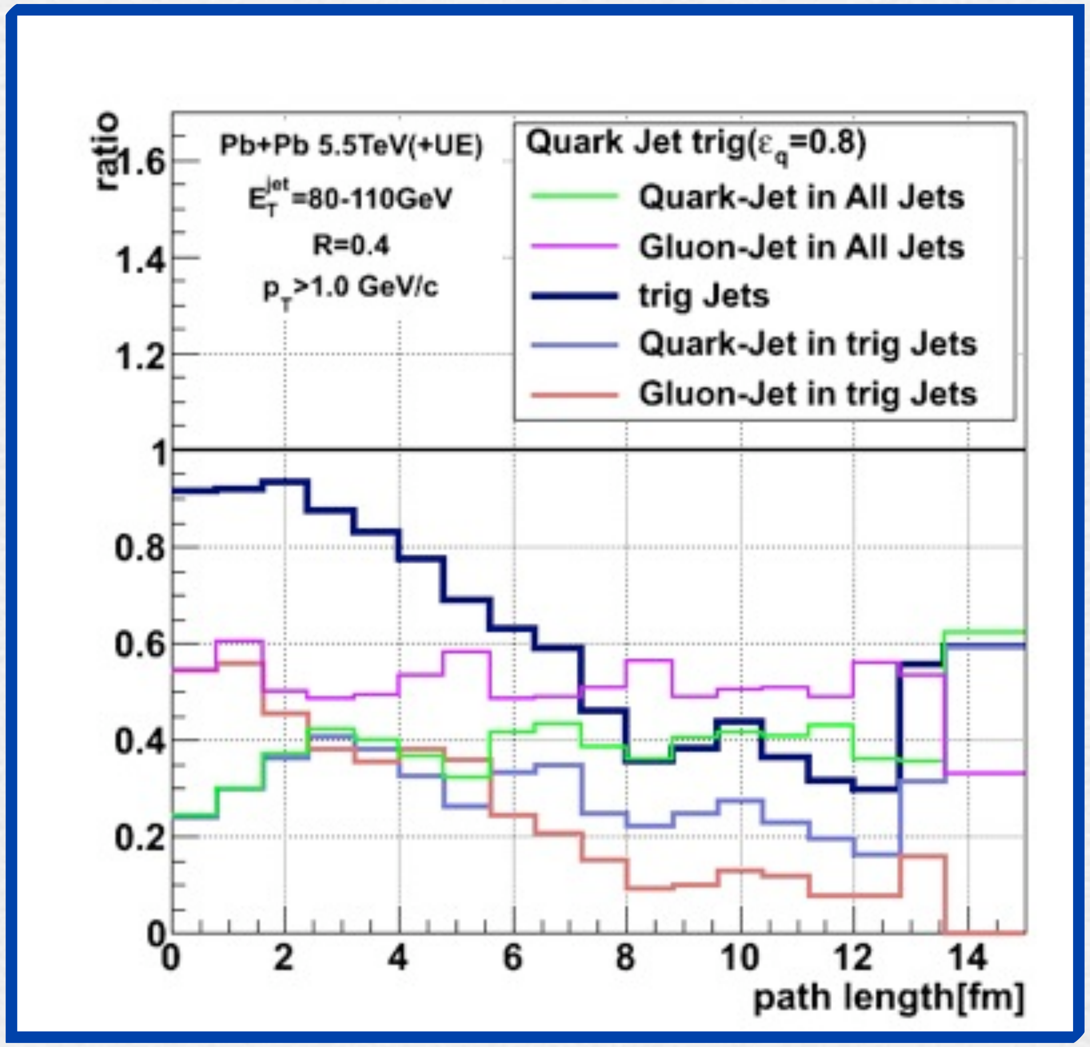




Surface Bias

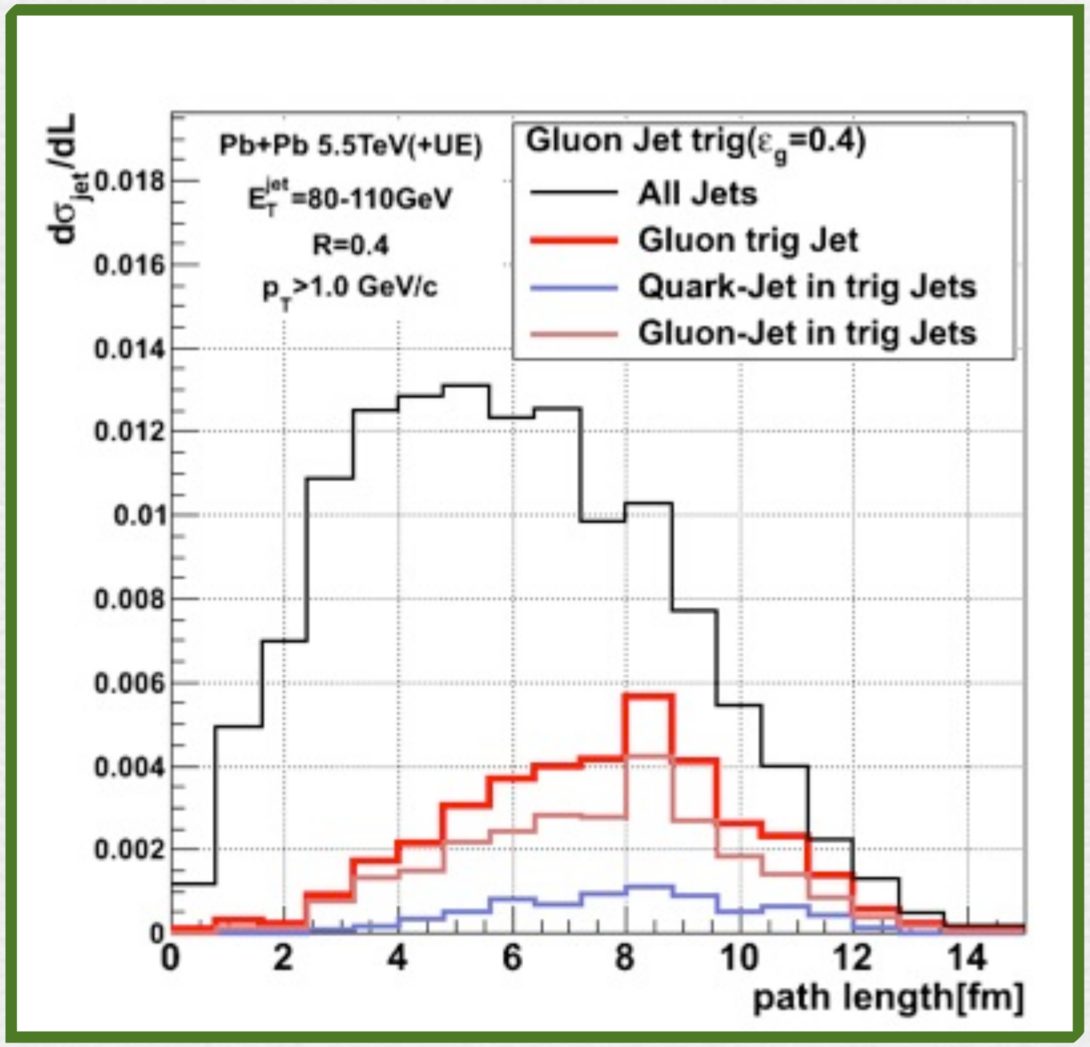
Quark-Jet Trigger (ε_q=0.8)

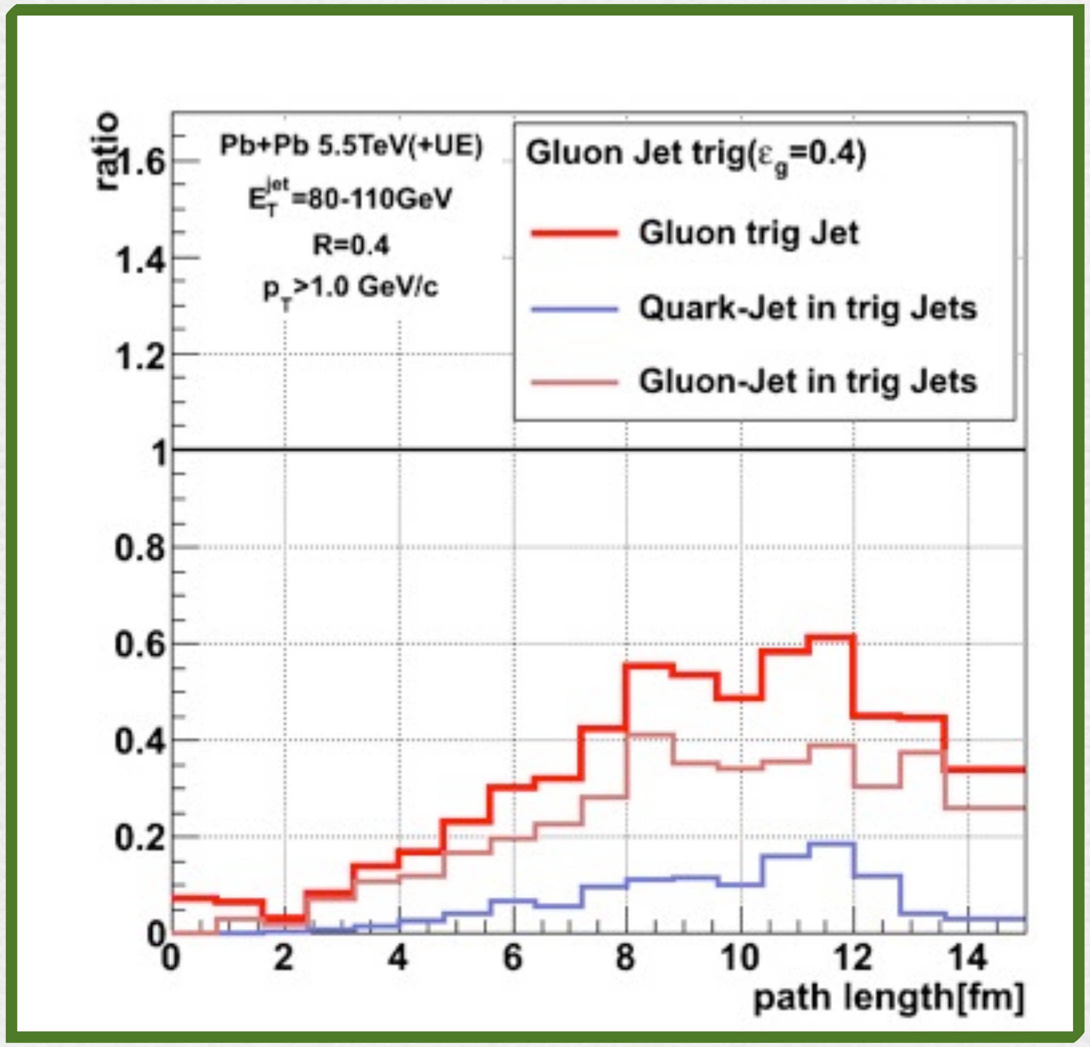




Surface Bias

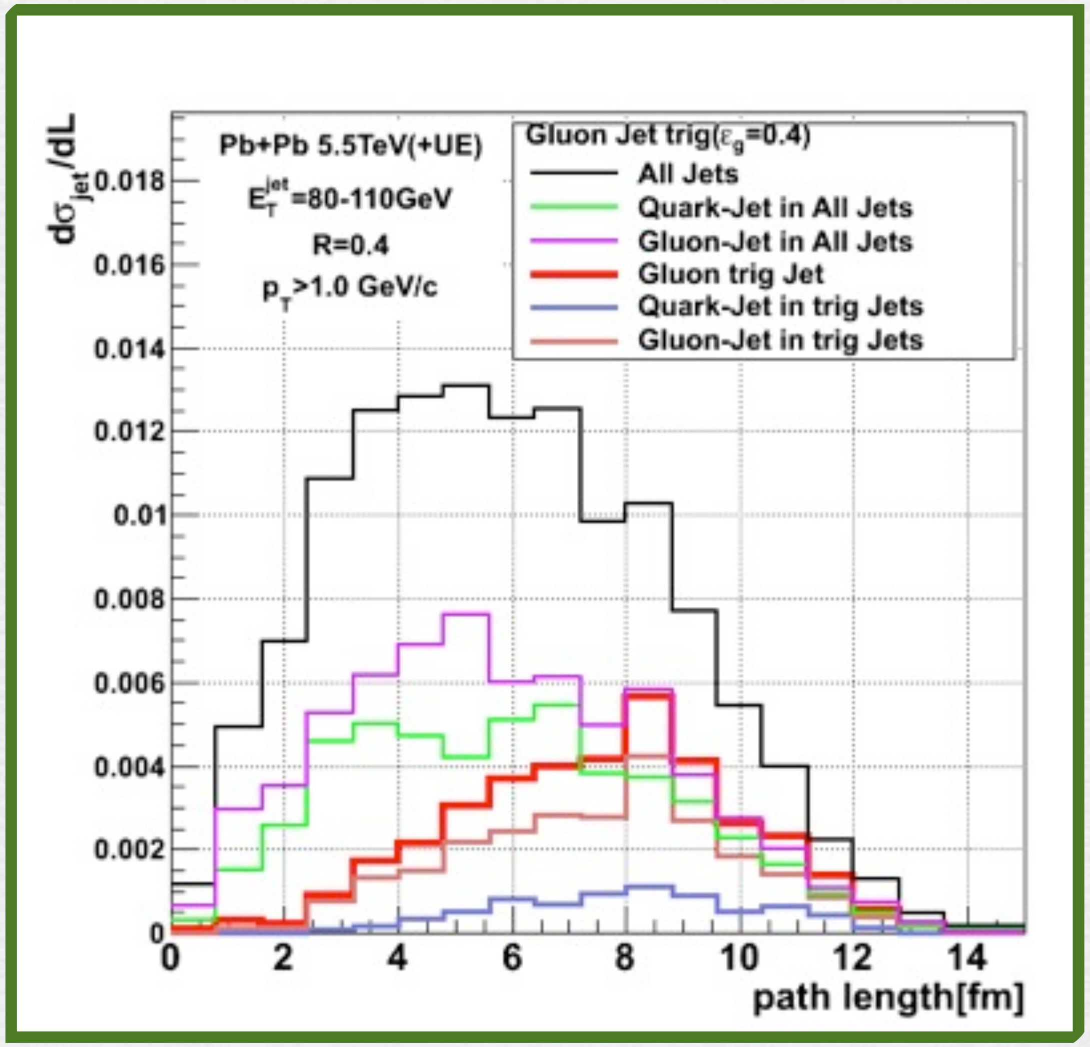
Gluon-Jet Trigger (ε_g=0.4)

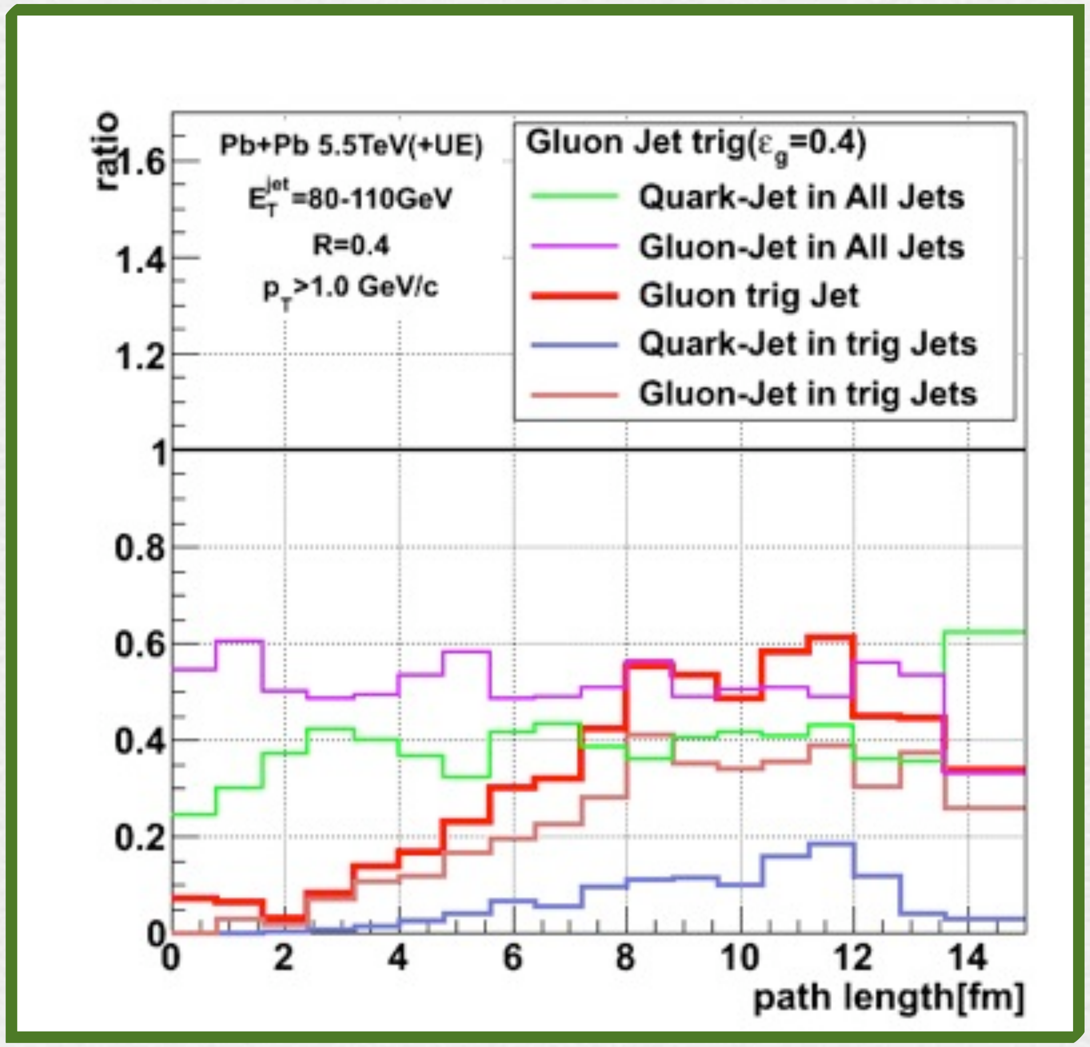




Surface Bias

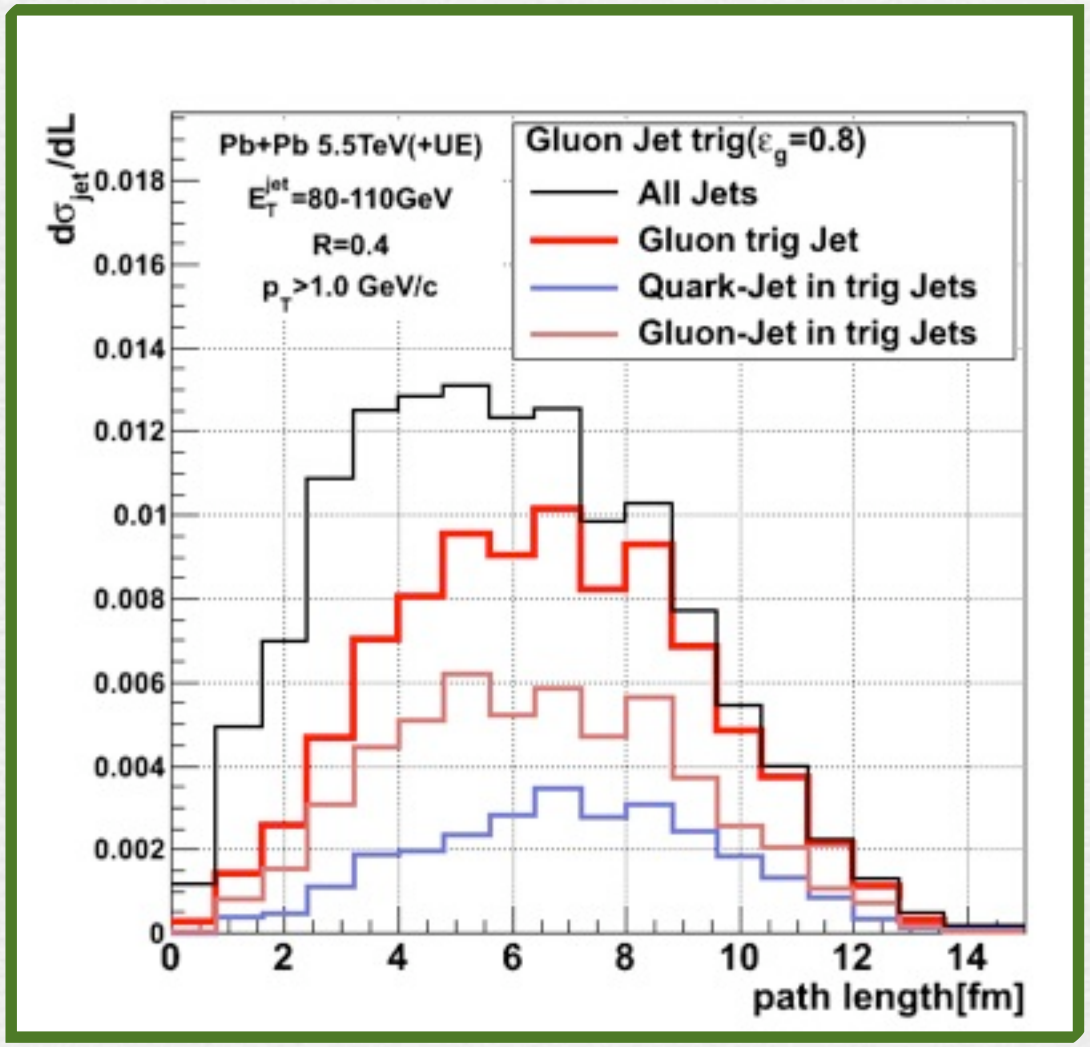
Gluon-Jet Trigger (ε_g=0.4)

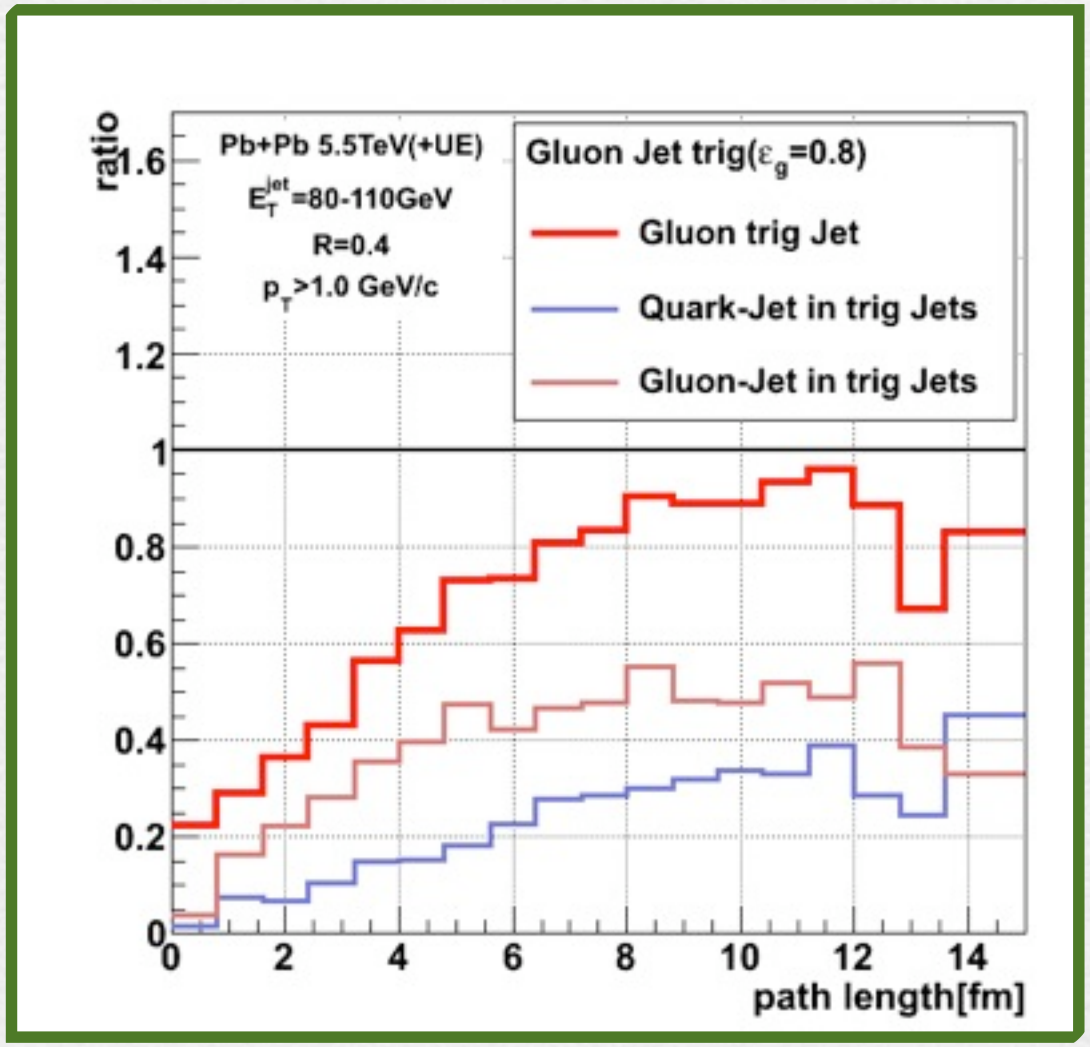




Surface Bias

Gluon-Jet Trigger (ε_g=0.8)





Surface Bias

Gluon-Jet Trigger (ε_g=0.8)