Fragmentation of charged-particle jets in pp collisions with ALICE

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ALICE

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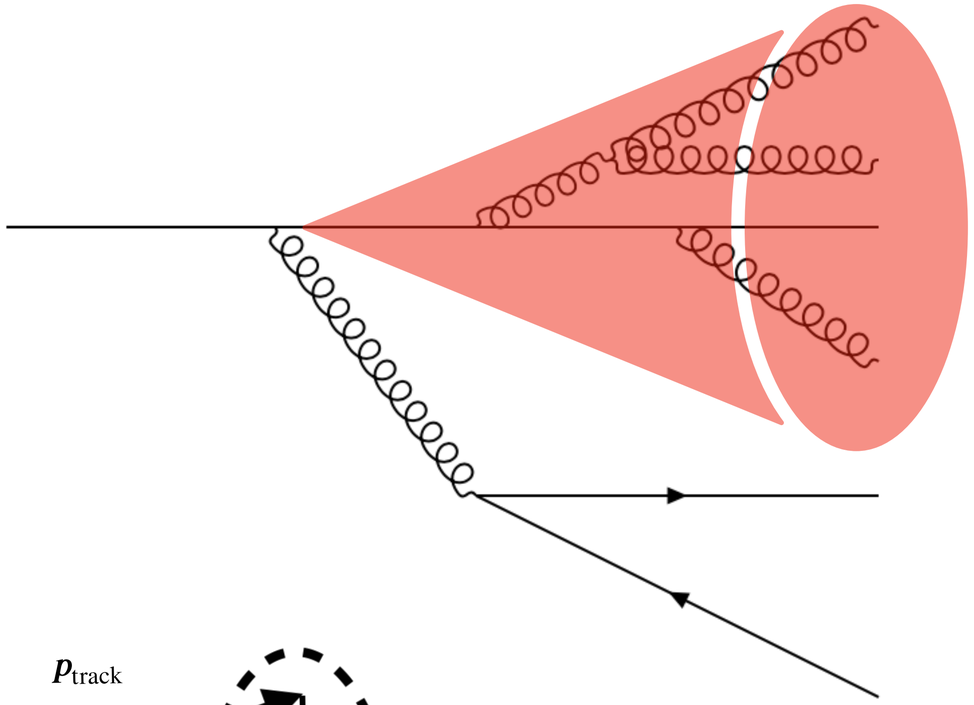
Jets

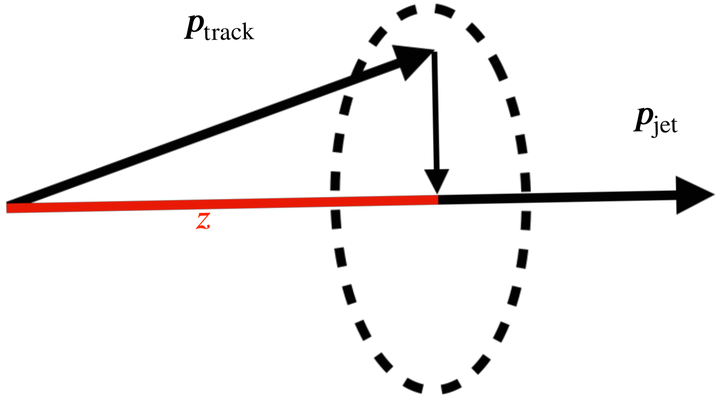
Energetic spray of particles

Longitudinal momentum fraction

$$z = \frac{\mathbf{p}_{\mathrm{i}} \cdot \mathbf{p}_{\mathrm{jet}}}{p_{\mathrm{jet}}^2}$$

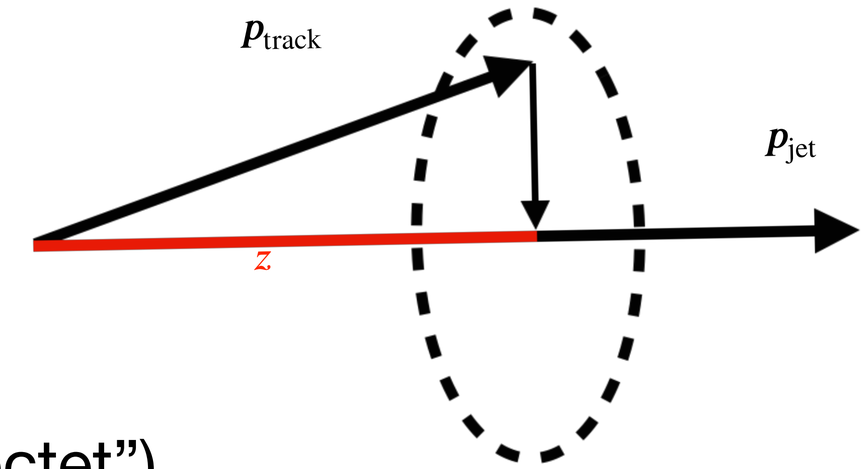
Initiated by quark or gluon





Fragmentation

$$z = \frac{\mathbf{p}_{\mathrm{i}} \cdot \mathbf{p}_{\mathrm{jet}}}{p_{\mathrm{jet}}^2}$$

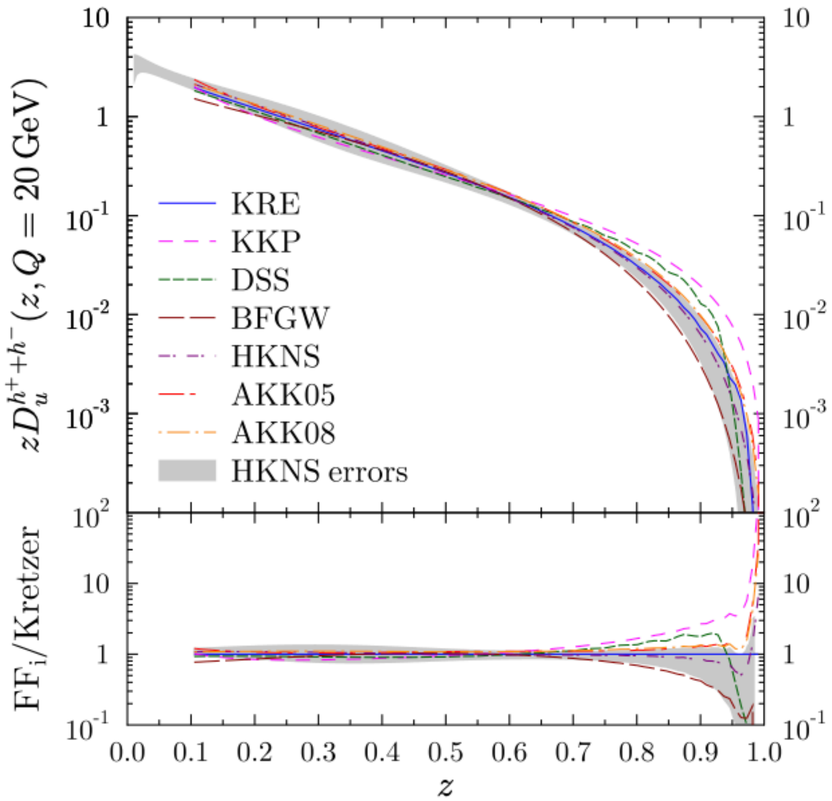


Expected to be different for quarks and gluons because gluons carry colour-anticolour charge (“octet”)

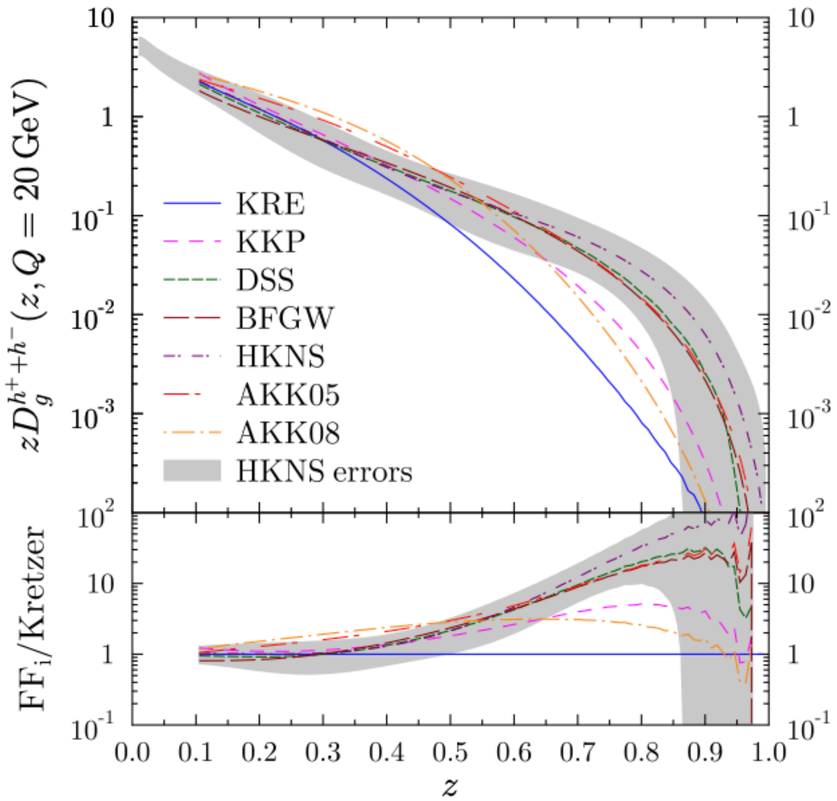
Fragmentation probes non-perturbative QCD

Motivation: theory

Quarks



Gluons



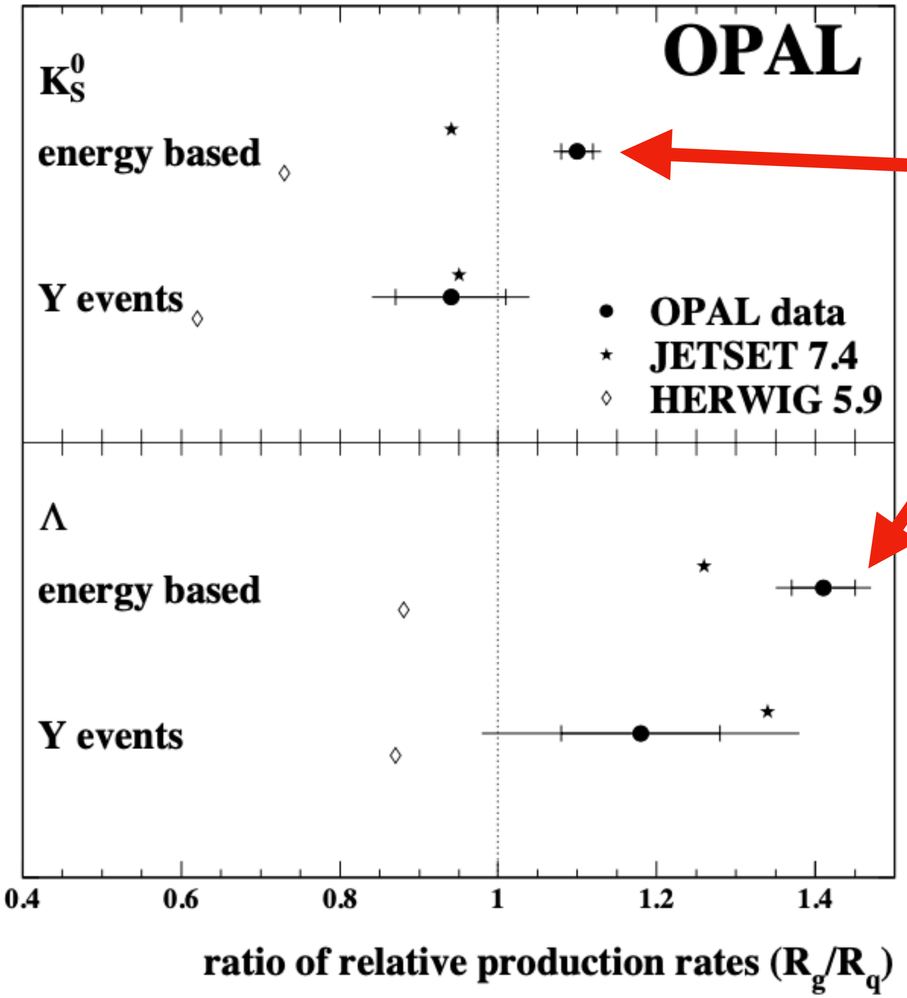
Gluon fragmentation poorly constrained

Number density of (charged) particles with momentum fraction z

d'Enterria et al. Nucl. Phys. B 883

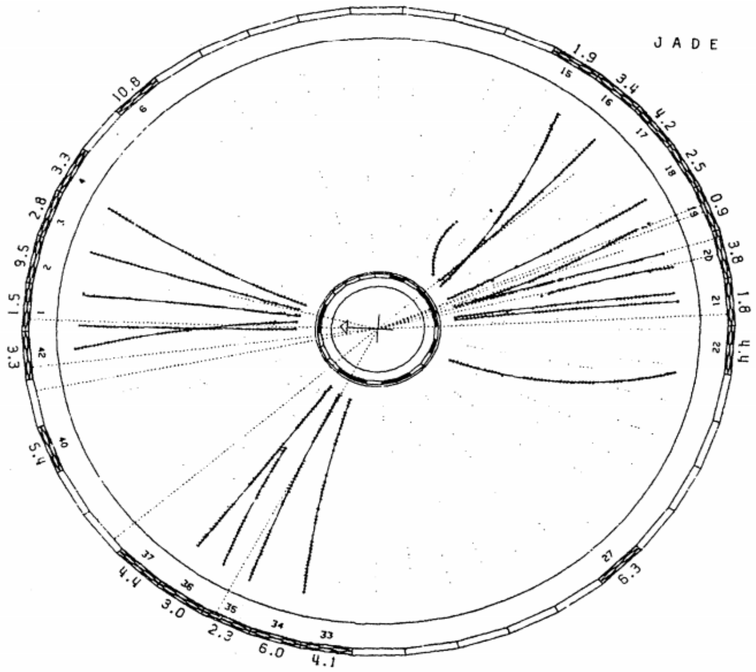
OPAL: Eur. Phys. J. C 8, 241–254 (1999)

Motivation: experiment



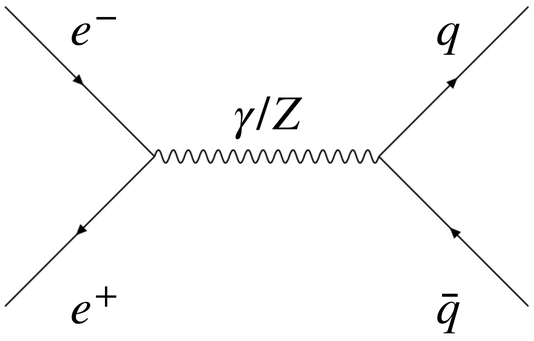
More K_S^0 in gluon jets

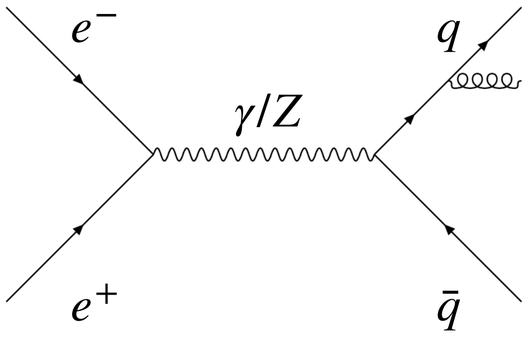
Λ^0 is more enhanced than K_S^0



JADE, Rev. Mod. Phys. 54 (2), 325-387 (1982)

e^+e^- collisions





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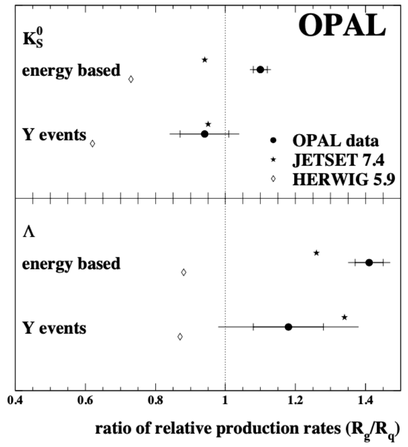
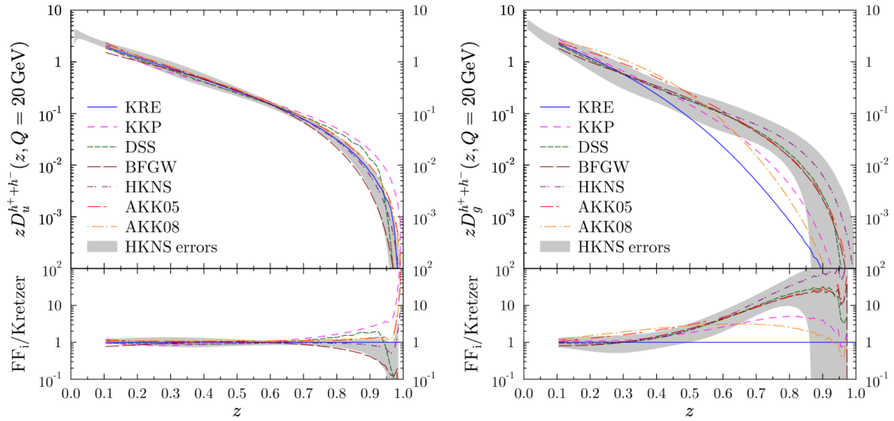
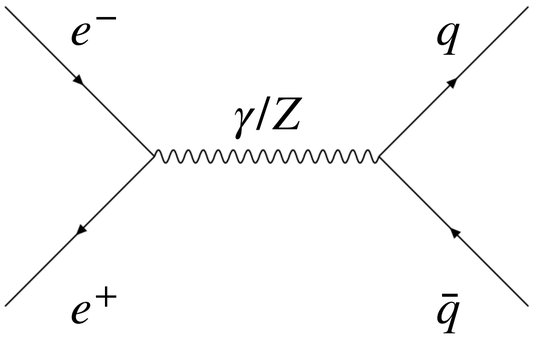
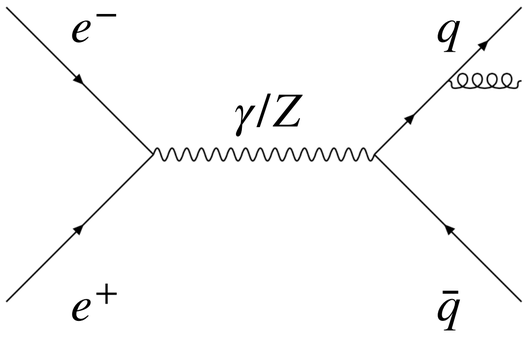




d'Enterria et al. Nucl. Phys. B 883

e^+e^- collisions





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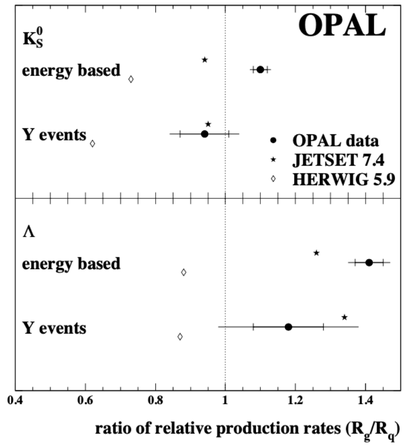
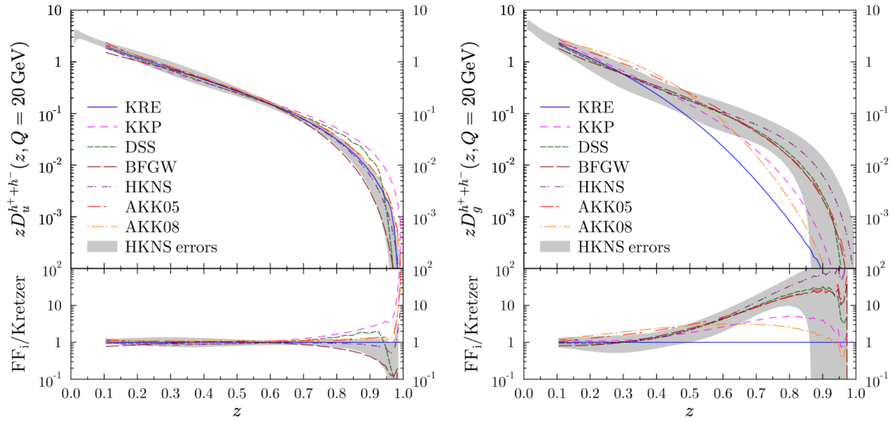


Fits made to e^+e^- data



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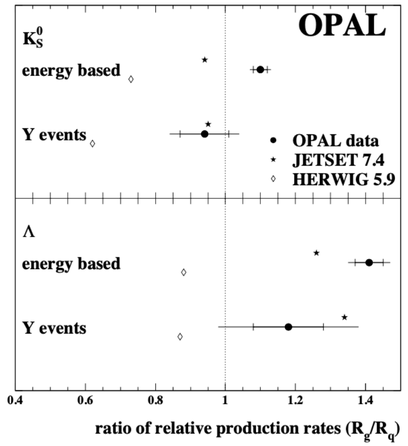
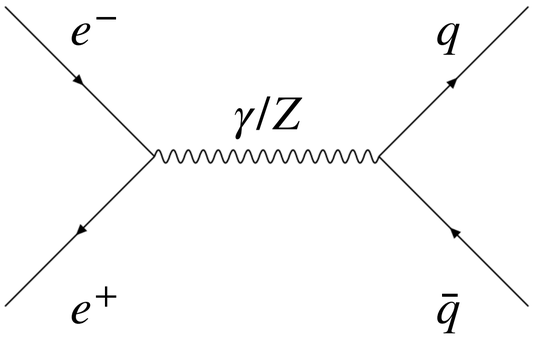
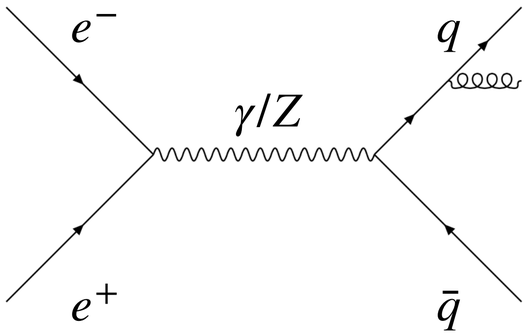
e^+e^- collisions

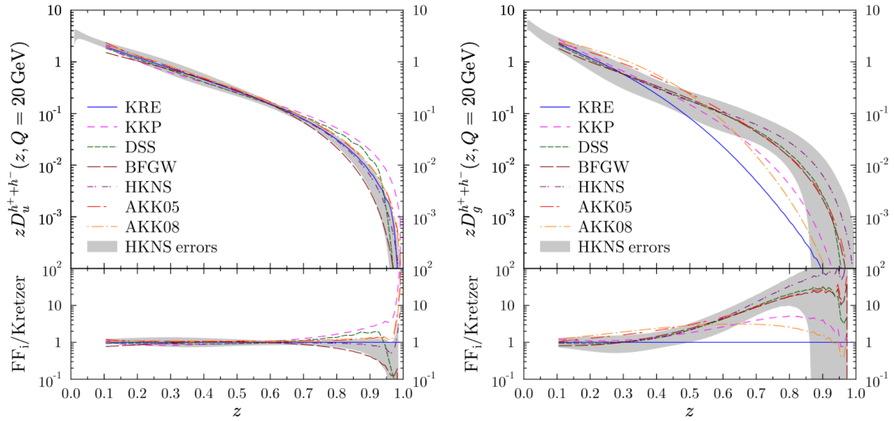






Fits made to e^+e^- data

+ Clean signal



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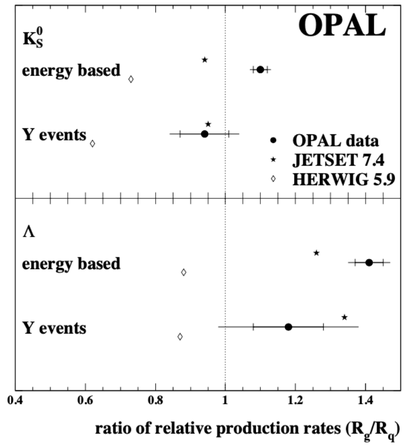
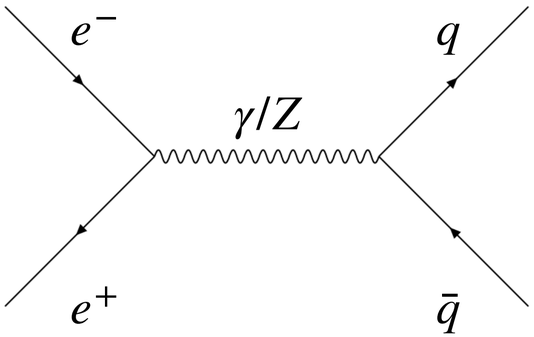
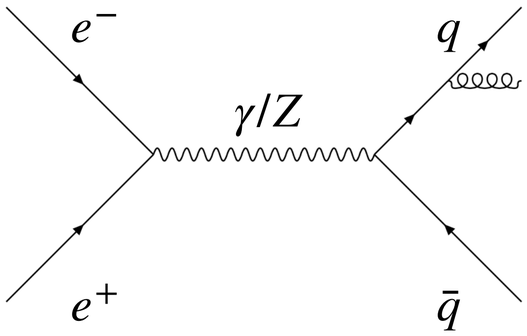
e^+e^- collisions



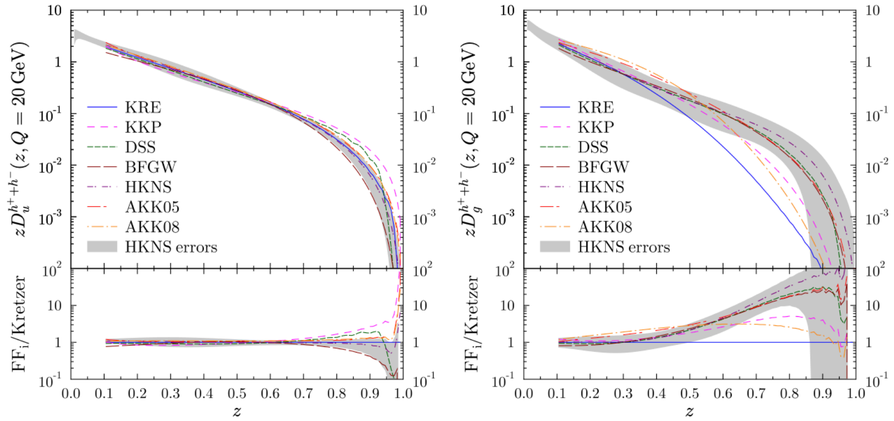




Fits made to e^+e^- data

+ Clean signal

+ Allows for q/g tagging of jets



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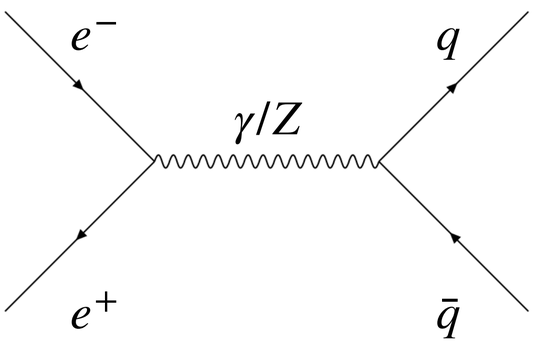
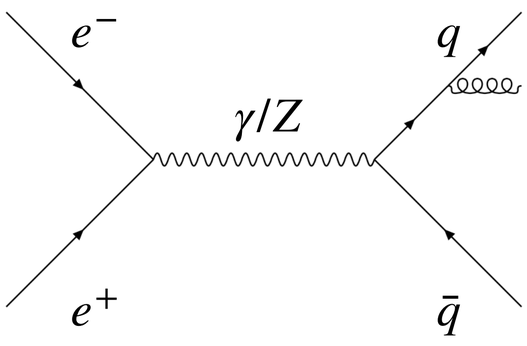
e^+e^- collisions





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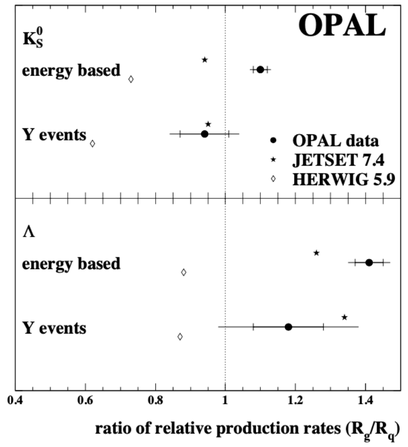
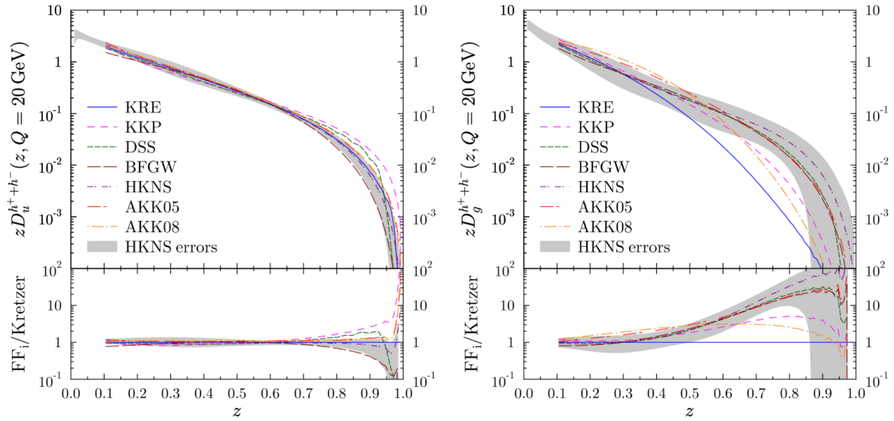


Fits made to e^+e^- data

+ Clean signal

+ Allows for q/g tagging of jets

- Access to gluons at NLO only



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ALICE Run 3 pp

Fits made to e^+e^- data: mainly quark jets

pp collisions produce mainly gluon jets

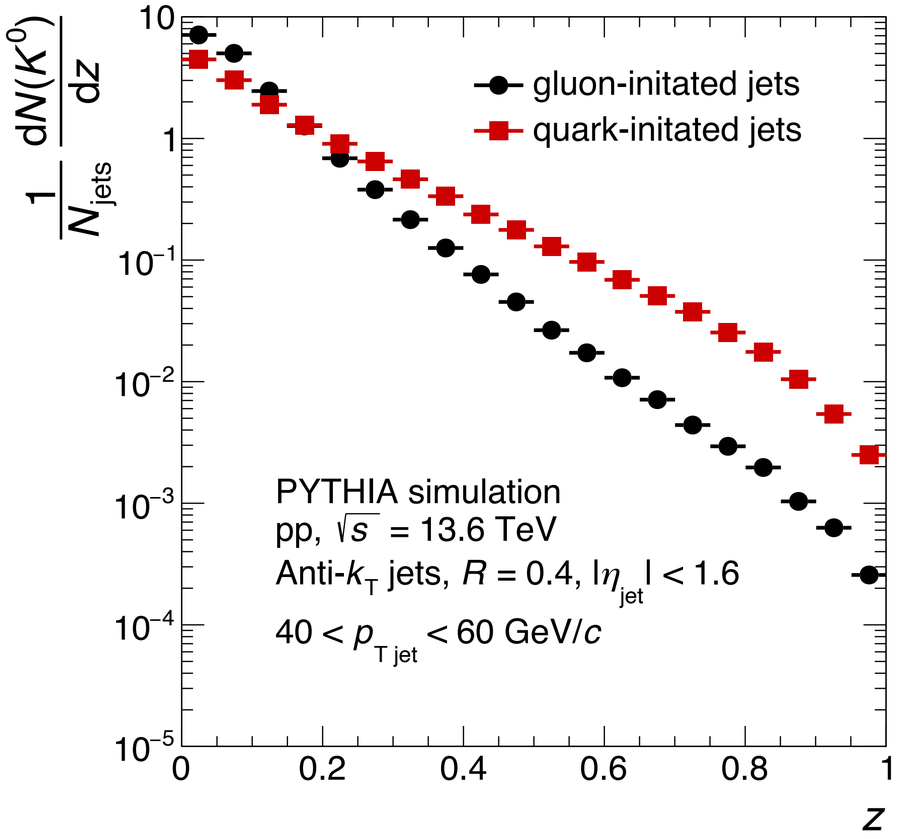
LHC Run 3 pp data has enough statistics to probe gluon fragmentation

Yields of Λ^0 and K_S^0 are different in quark jets and gluon jets

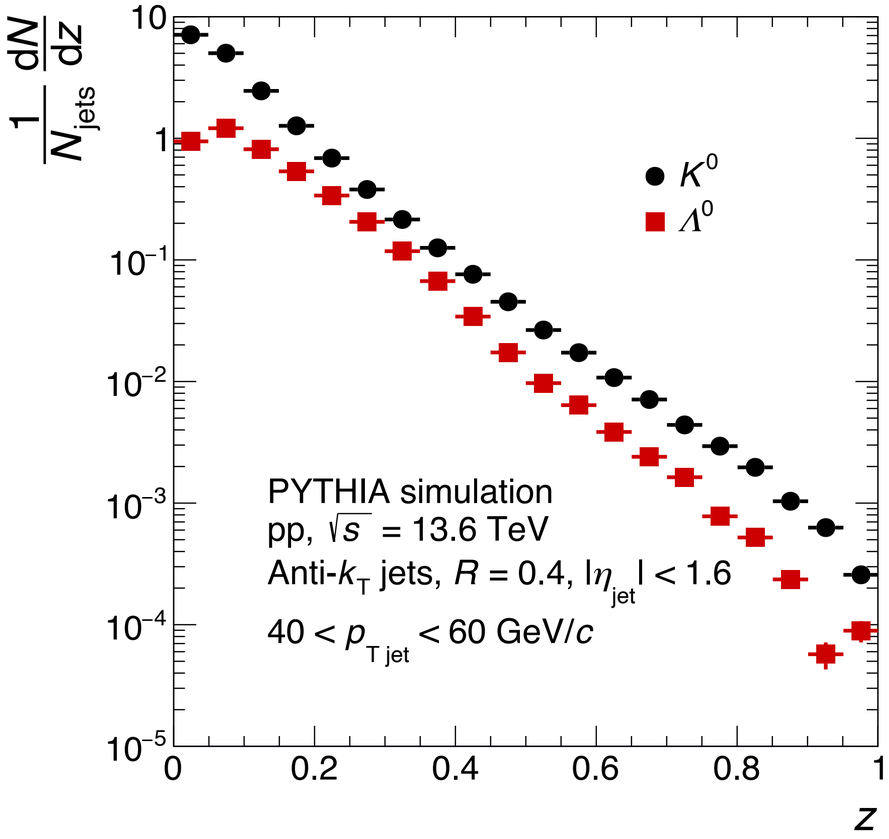
ALICE tracking efficiency and PID capabilities give us the necessary tools for this measurement

Monte Carlo Simulation

Gluons, quarks → K^0



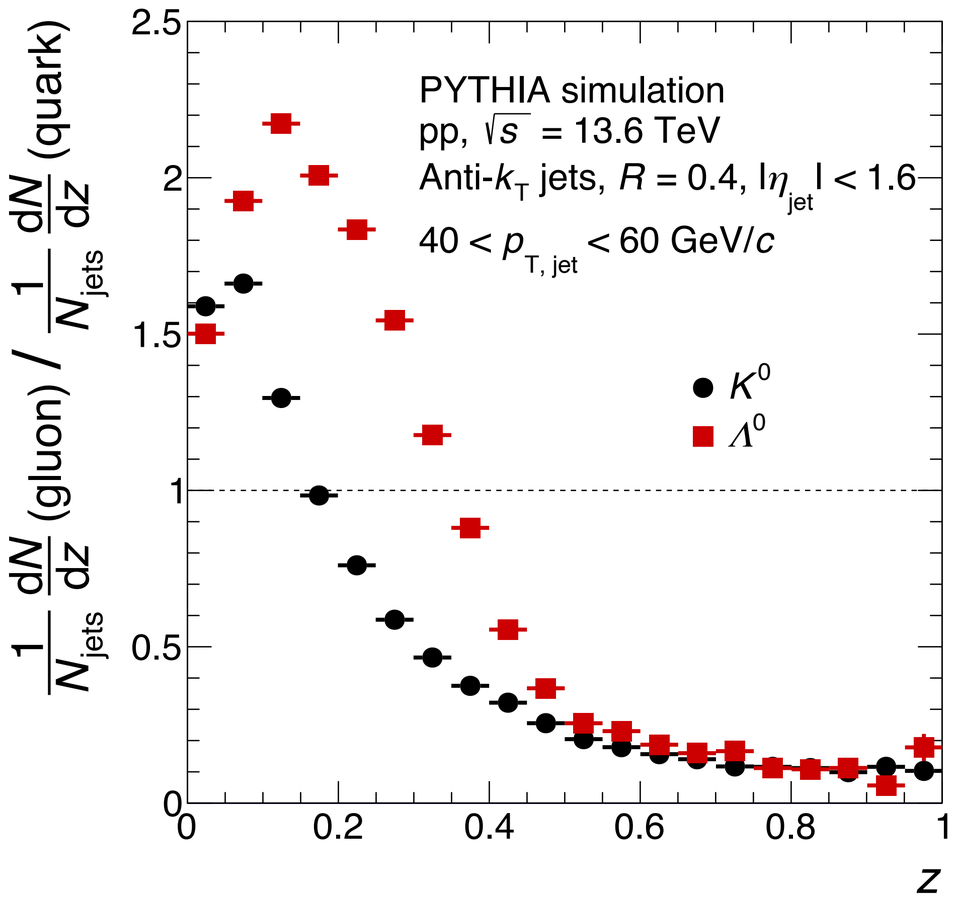
Gluons → K^0, Λ^0



Monte Carlo Simulation

Comparing gluon and quark jet fragmentation into Λ^0 and K^0

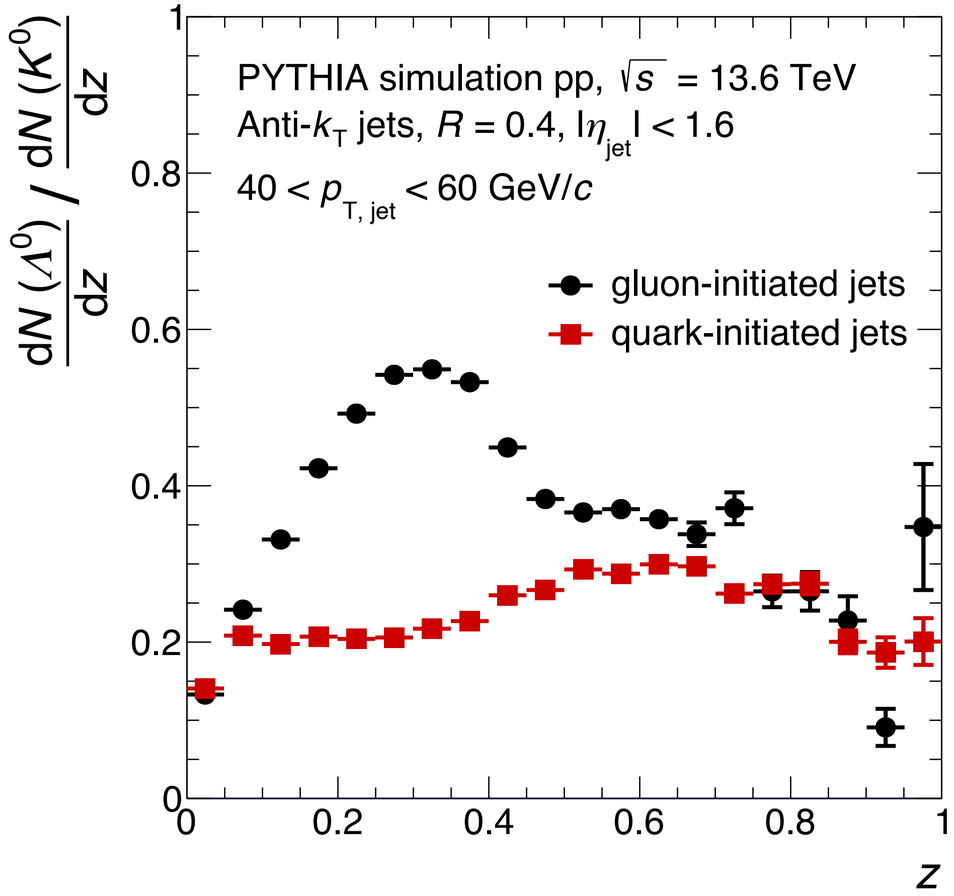
- Gluons have softer fragmentation
- Enhanced Λ^0 production in gluon jets at $z \leq 0.5$



PYTHIA

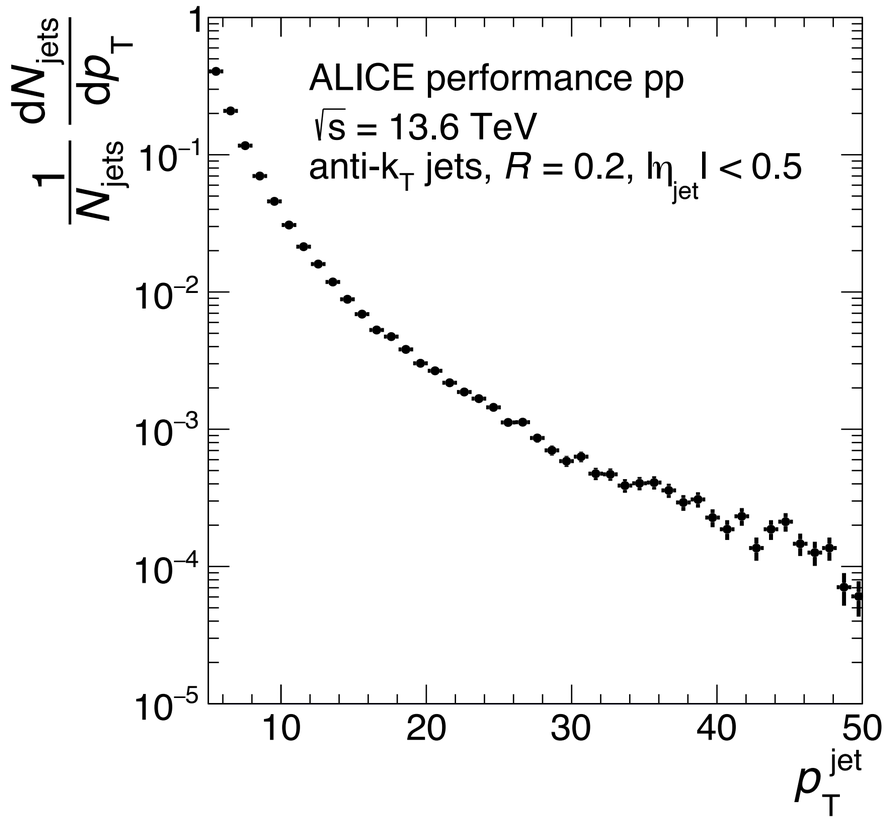
Λ^0/K^0 in gluon jets and quark jets

- Approximately independent of z for quark jets
- Significantly different in gluon jets



Jet Trigger 2022 Data

Trigger: R = 0.2 jet with $p_{\mathrm{T,jet}} > 8$ GeV/c



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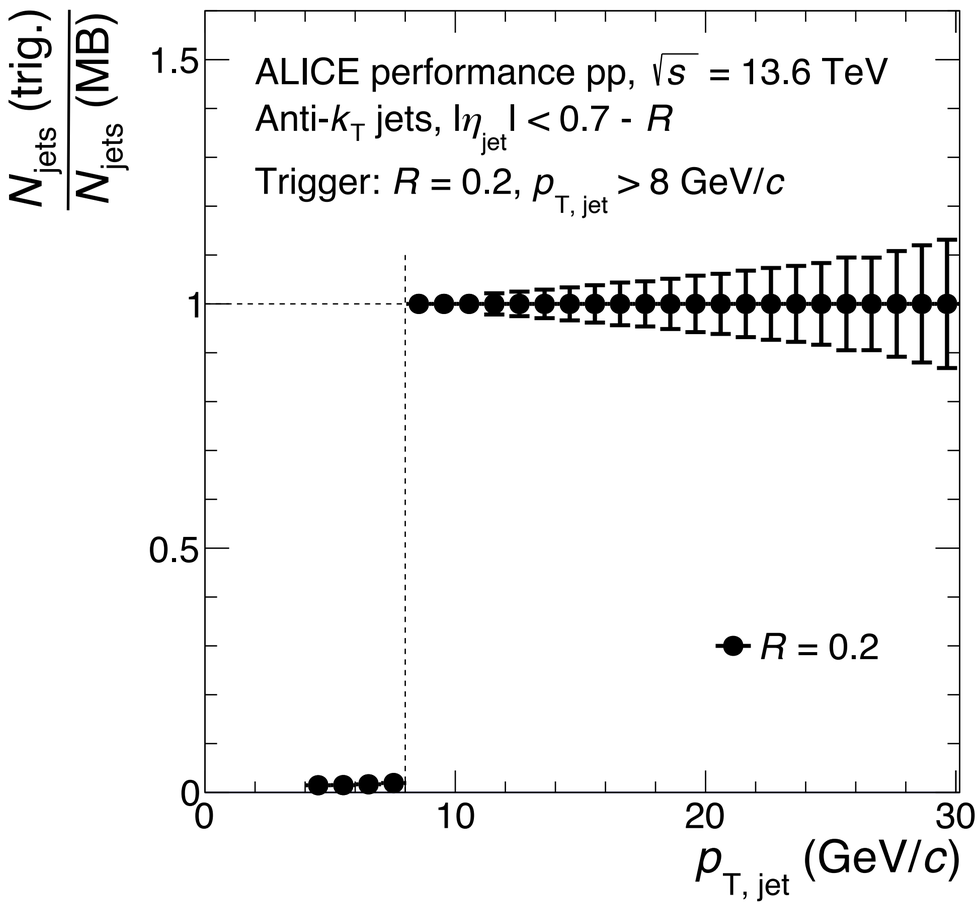
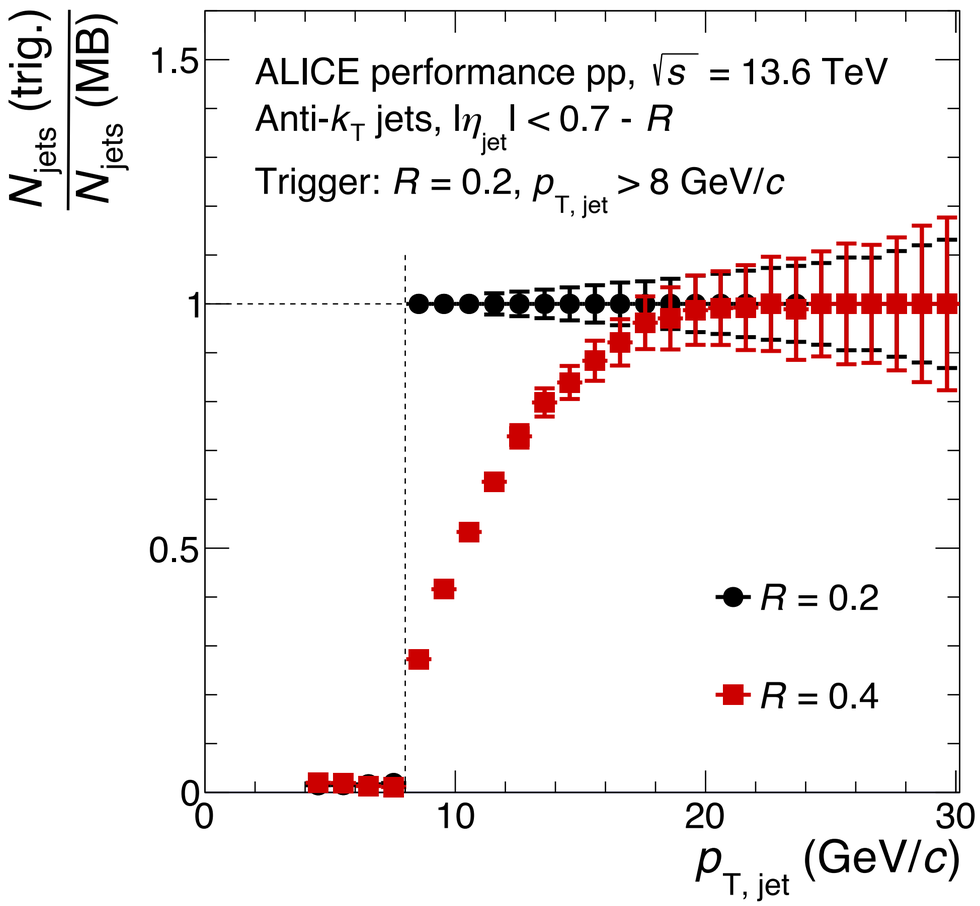


Jet Trigger 2022 Data

Trigger: R = 0.2 jet with $p_{\mathrm{T,jet}} > 8$ GeV/c

Jet yield for larger R modified far above threshold, up to 20 GeV/c

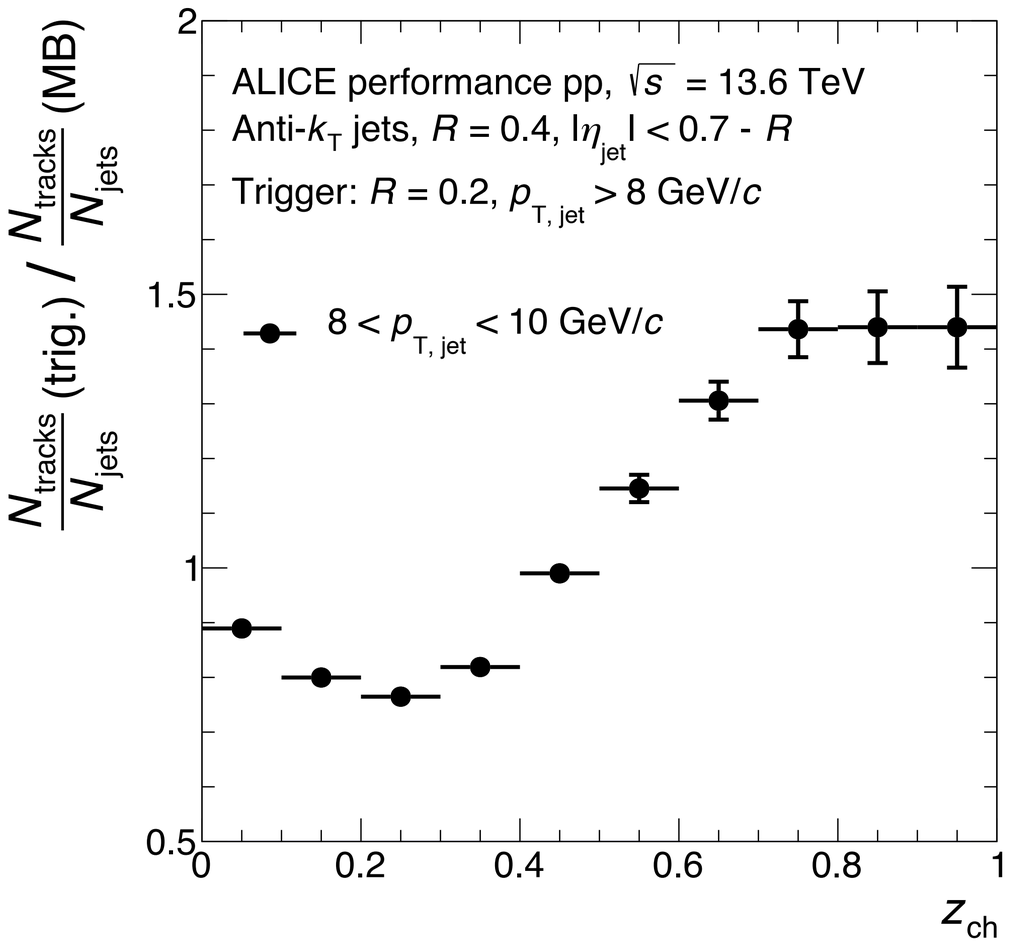
- Trigger leads to depletion of R = 0.4 jets in selected events



Jet Trigger 2022 Data

Trigger on R = 0.2 biases the R = 0.4 jet sample

- Close to threshold: strong bias towards jets with high z tracks



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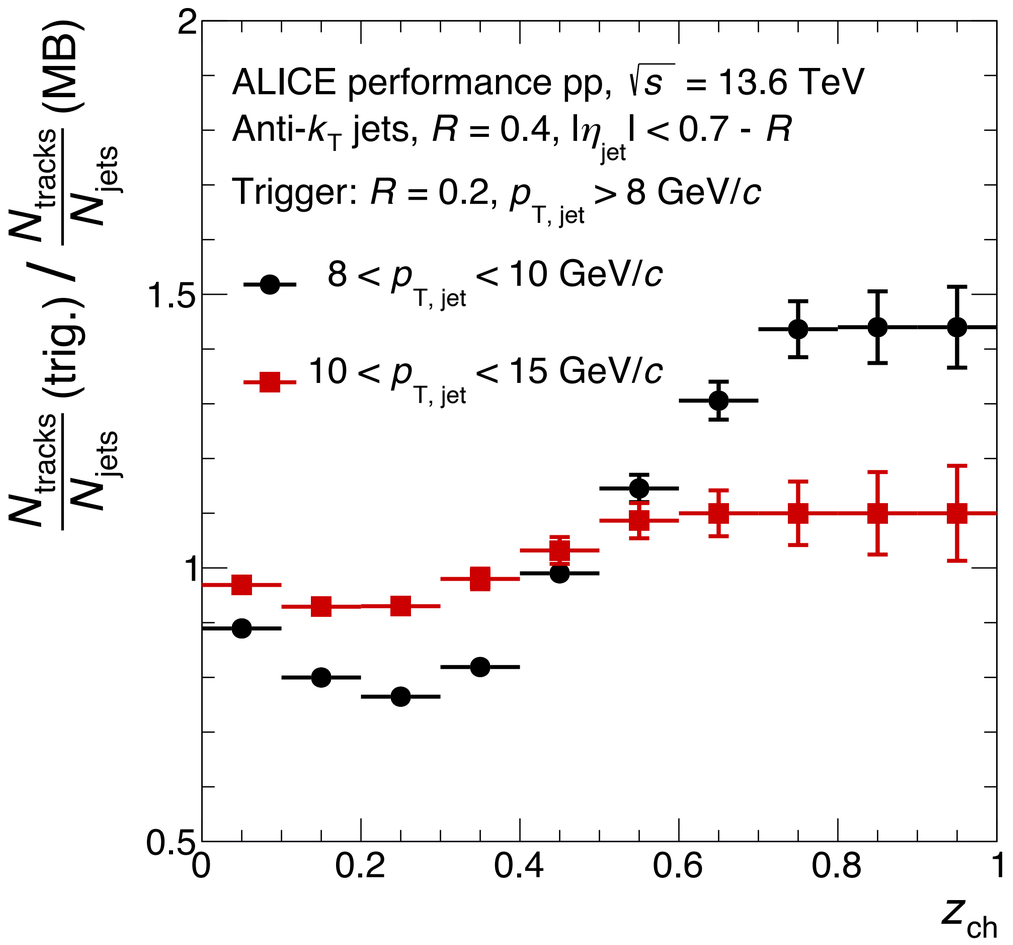
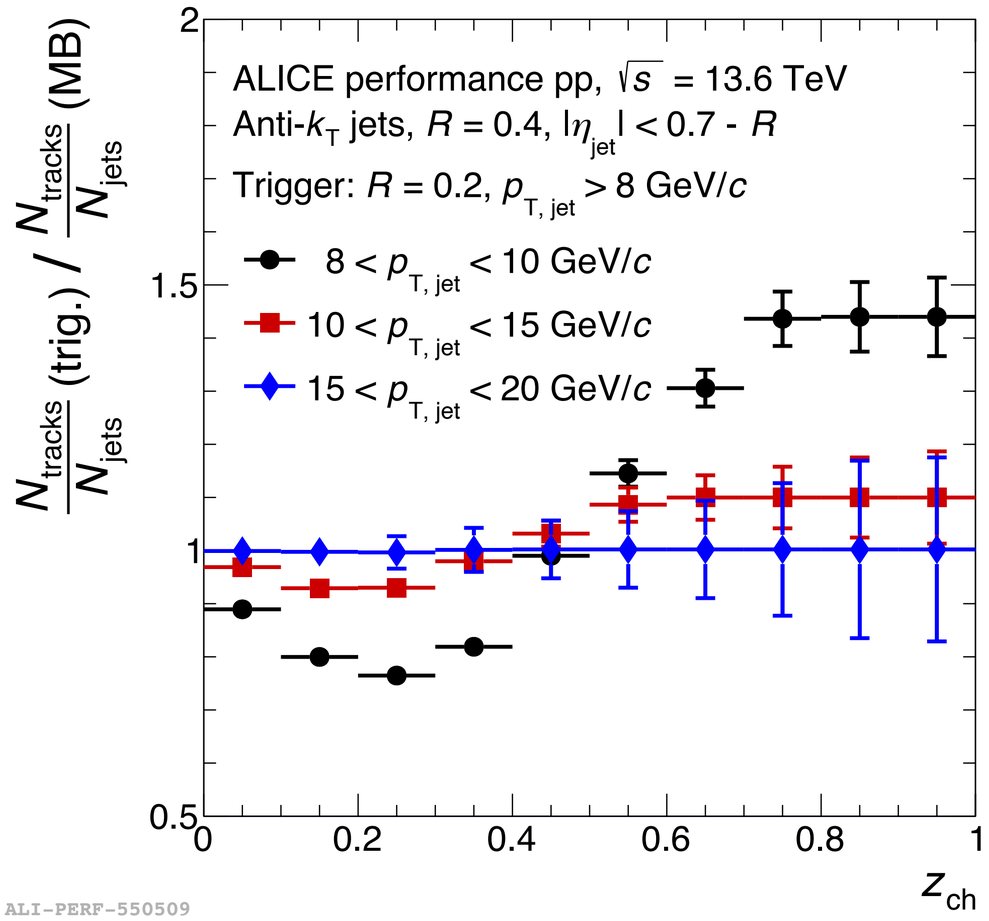


Jet Trigger 2022 Data

Trigger on R = 0.2 biases the R = 0.4 jet sample

- Close to threshold: strong bias towards jets with high z tracks

For $p_{\mathrm{T,jet}} >$ 20 GeV/c: bias-free sample



Detector Response

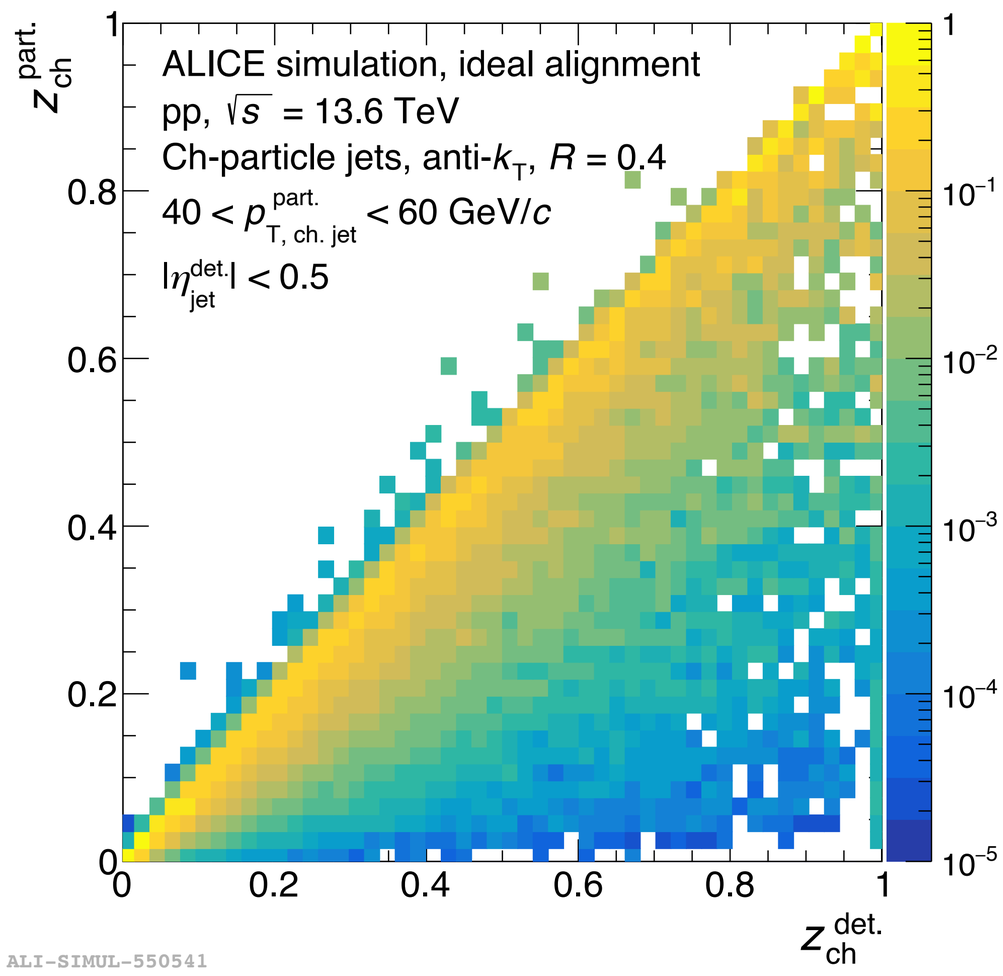
Compare PYTHIA at particle-level and detector-level

- Diagonal entries: $p_{\mathrm{T,jet}}$ unaffected
- Lower triangle: $p_{\mathrm{T,jet}}$ decreased (missed tracks)

Small spread around diagonal

- Observable robust to detector effects

Correct for detector resolution



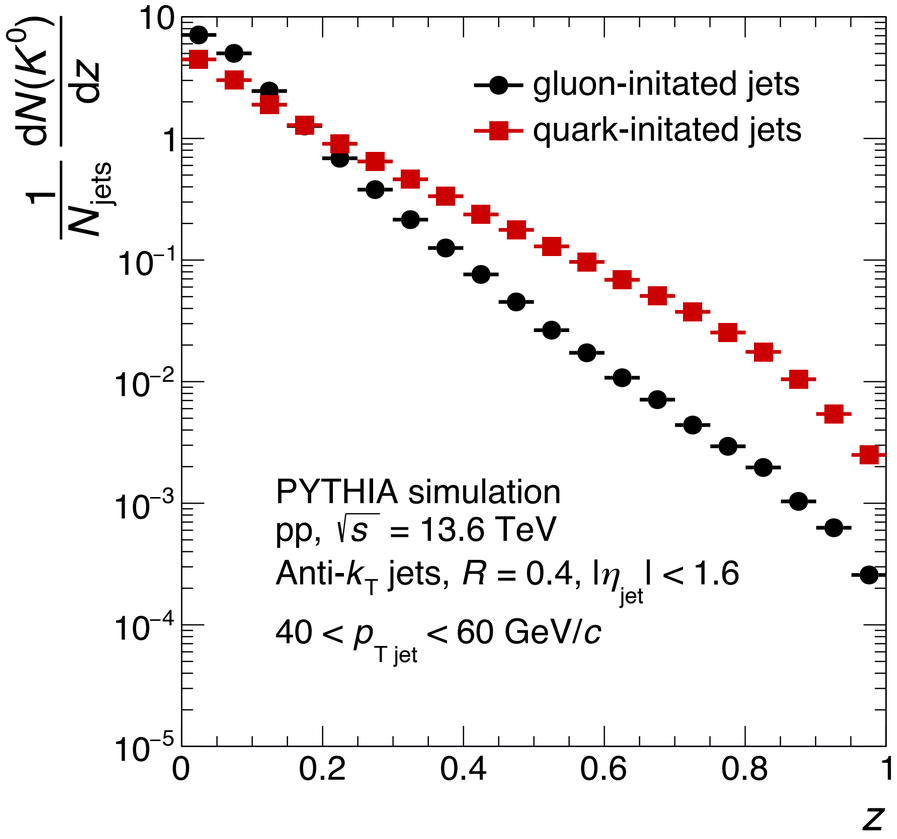
Summary

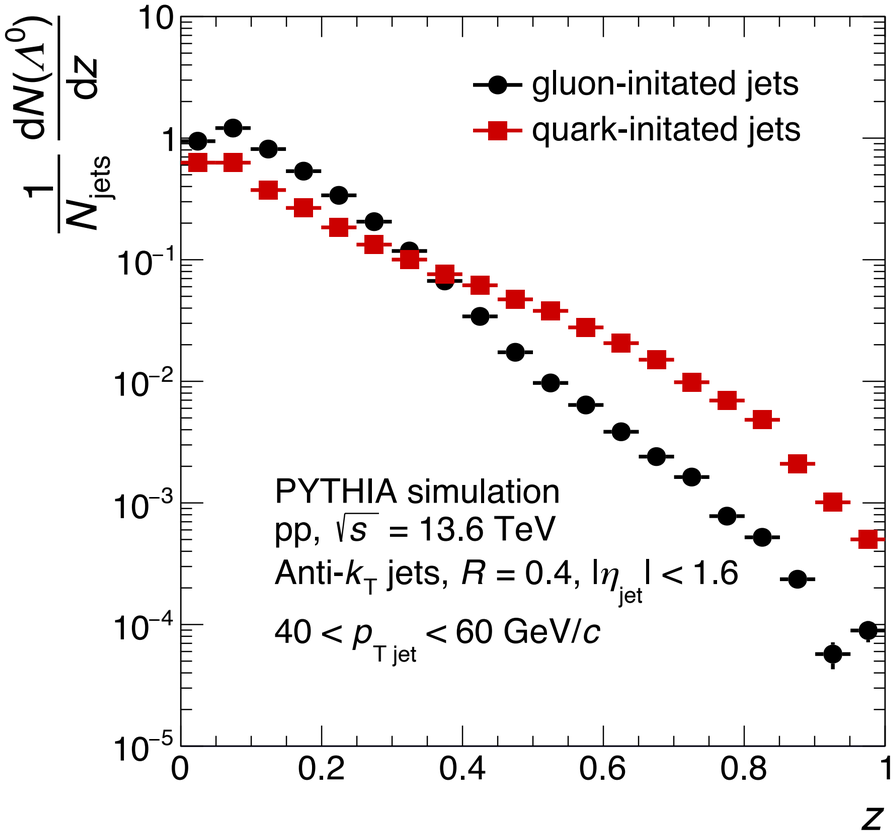
- Gluon fragmentation is theoretically poorly constrained
- Measurement of z in pp collisions for Λ^0, K_S^0 shows promise
- Gluon jets fragment into more, soft baryons
- Effects of trigger bias and detector response are well-understood
- Next: PID differential measurement with Run 3 ALICE pp data

Backup

PYTHIA

Fragmentation of quarks and gluons into K^0 and Λ^0

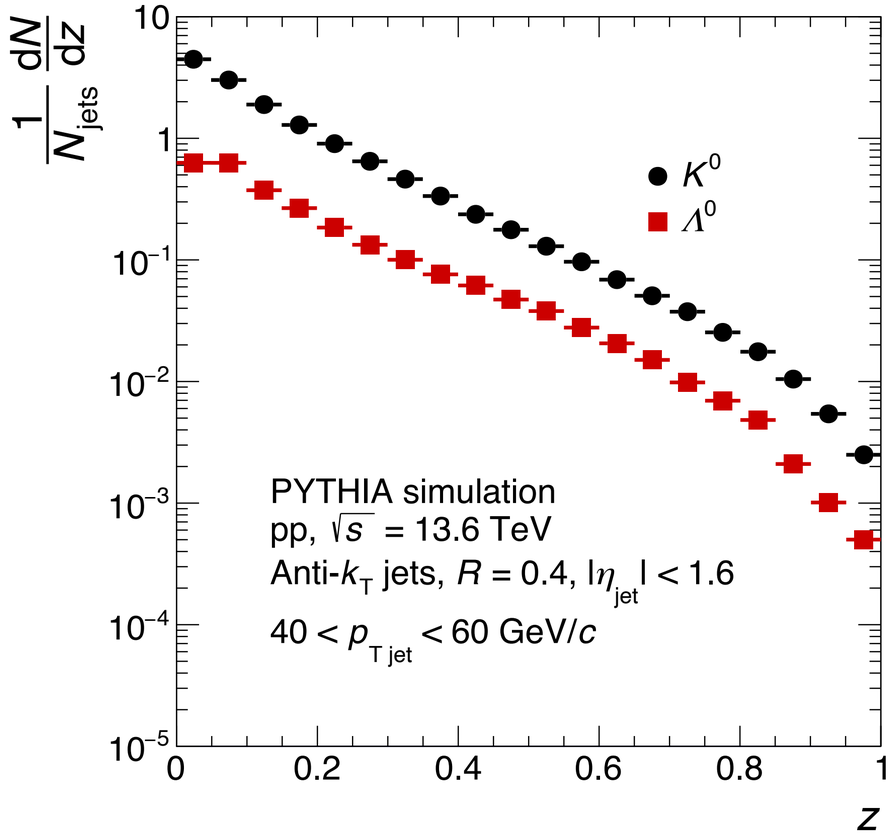




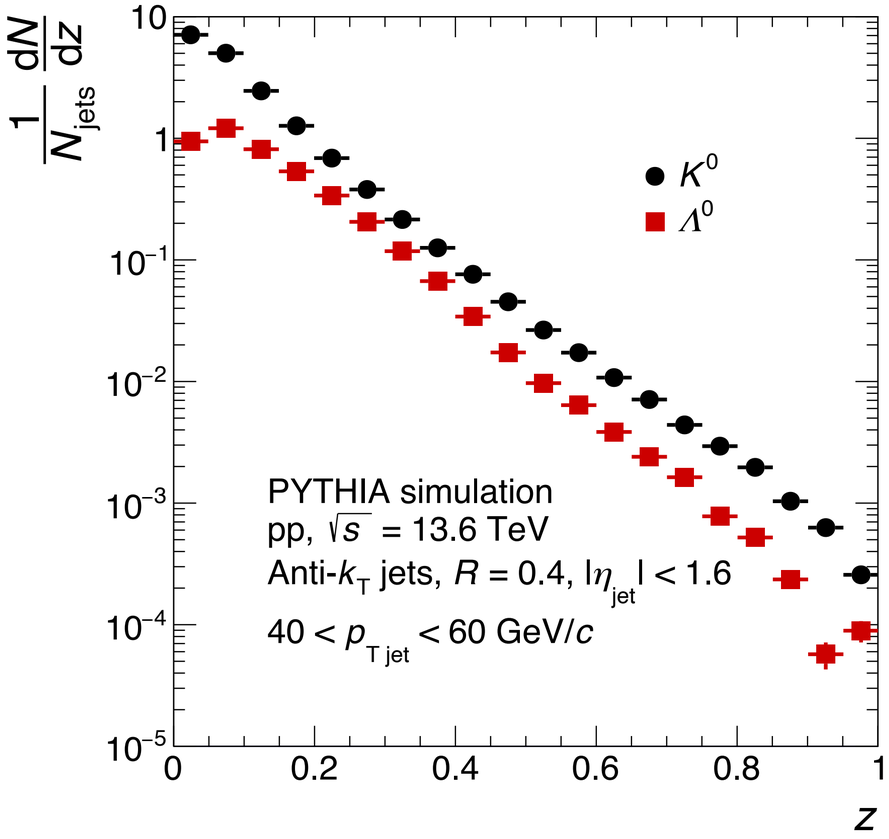
PYTHIA

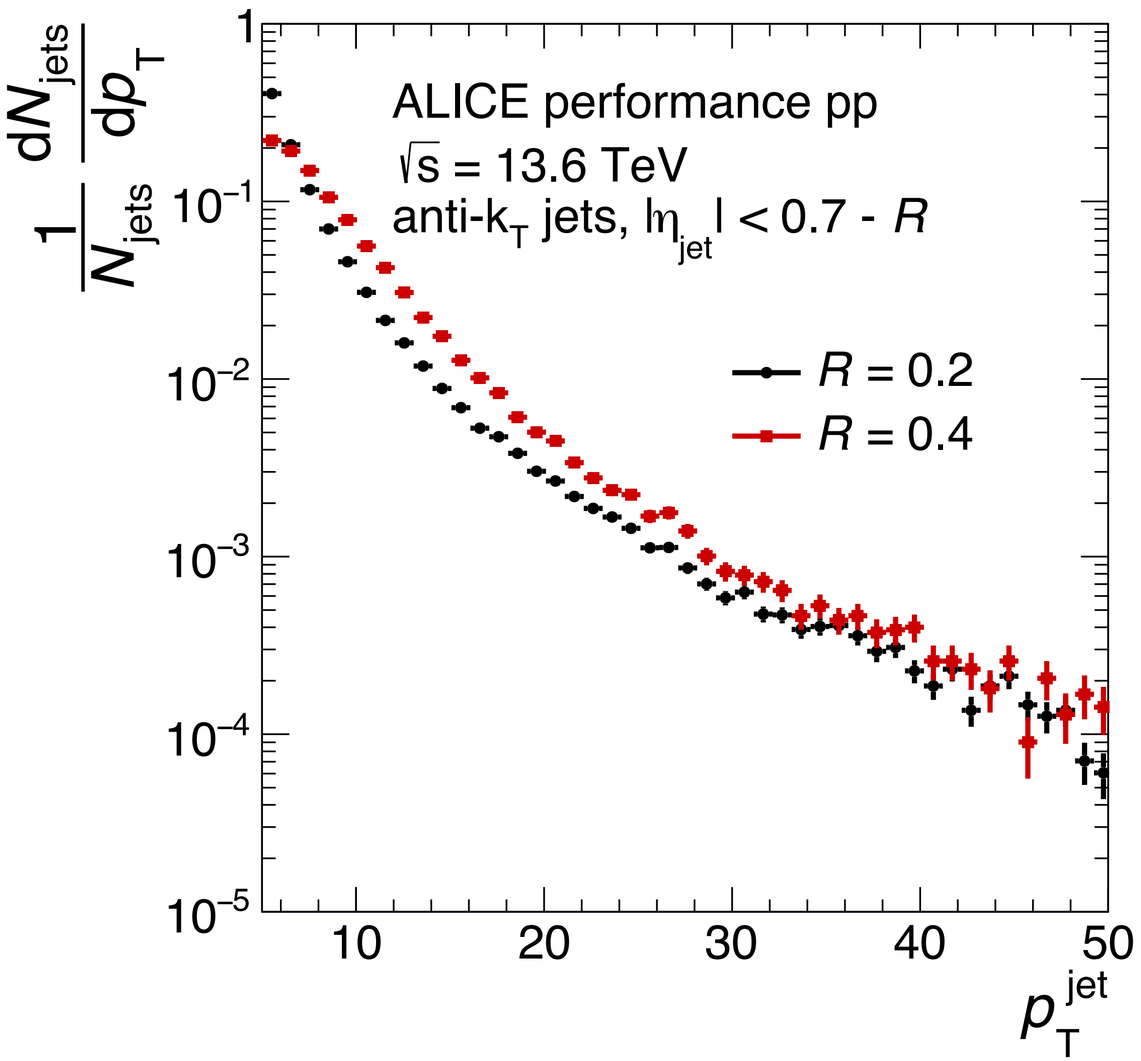
Fragmentation of quarks and gluons into K^0 and Λ^0

Quarks



Gluons




ALICE performance pp
√s = 13.6 TeV
anti-k_T jets, |η_jet| < 0.7 - R
R = 0.2
R = 0.4
1/N_jets dN_jets/dp_T
p_T^jet
1
10^−1
10^−2
10^−3
10^−4
10^−5
10
20
30
40
50