First measurement of jet angularities with D^0-meson tagged jets

Preeti Dhankher

On behalf of the ALICE collaboration

University of California, Berkeley

Hard Probes 2023

03/29/2023

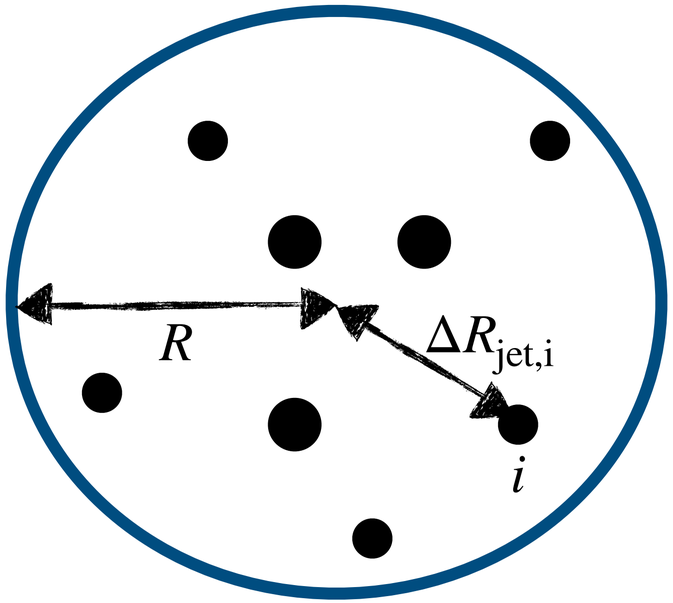
What are the jet angularities?

A. Larkoski, J. Thaler, W. Waalewijn
JHEP 11 (2014) 129

Ezra Lesser
Tuesday 5:10 pm

- A set of **substructure observables** which are dependent on the p_T and angular distribution of tracks within jets:

$$\lambda_\alpha^\kappa = \sum_{i \in jet} \left(\frac{p_{T,i}}{p_{T,jet}} \right)^\kappa \left(\frac{\Delta R_{jet,i}}{R} \right)^\alpha$$



Jet p_T fraction carried by constituent i

$\Delta R_{jet,i}$ distance of constituent i to the jet axis

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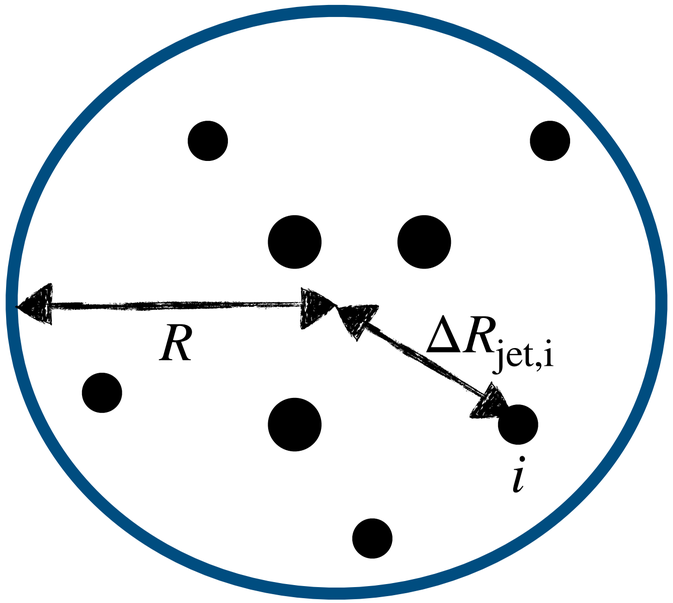

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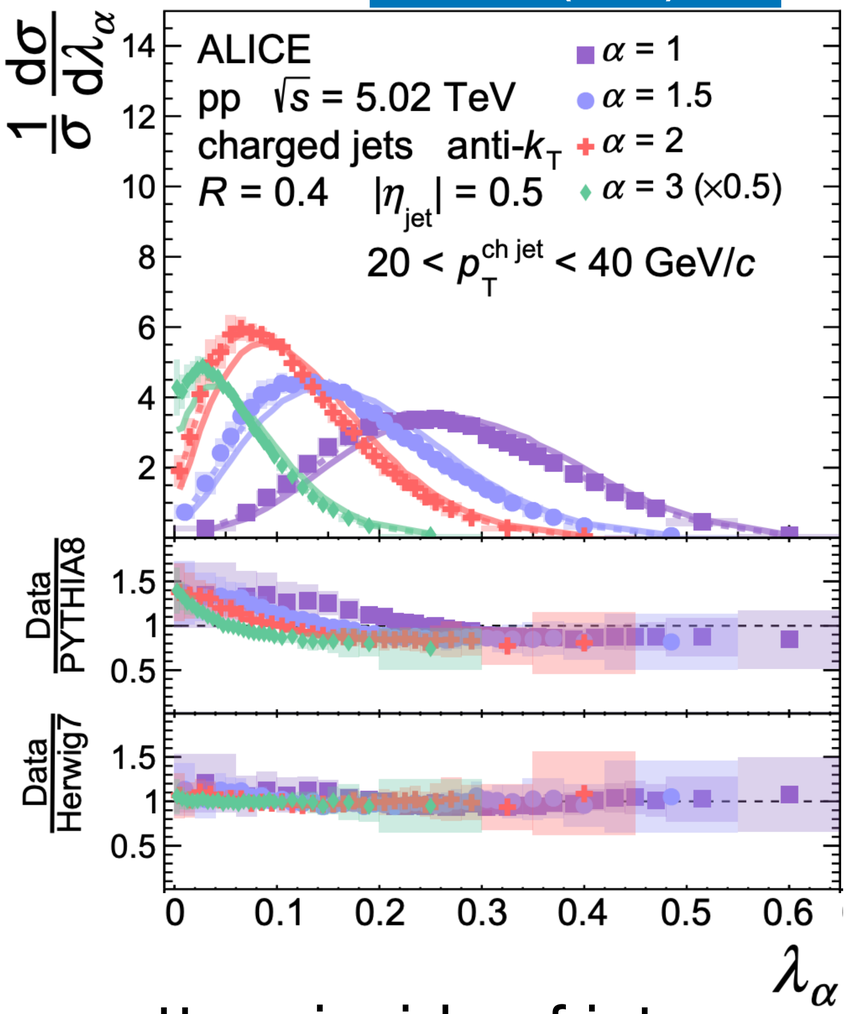
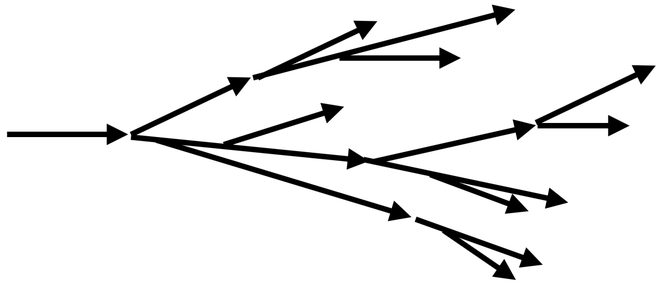
JHEP05 (2022) 061



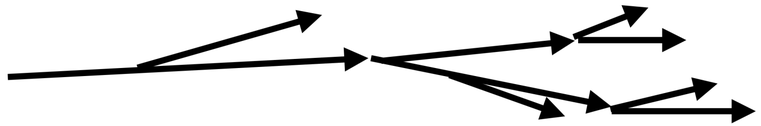
- Infra-Red and Collinear (IRC) safe observable for $\kappa = 1$, $\alpha > 0$ → calculable from pQCD.
- Each α defines a different observable
  → varying α systematically characterizes the radiation pattern inside of jets

Flavour dependence in the QCD shower

Gluon-initiated shower



Quark-initiated shower



$$\frac{C_A}{C_F} = \frac{9}{4}$$

Casimir color factors

Gluon-initiated showers are expected to have a broader and softer fragmentation profile than quark-initiated showers

Flavour dependence in the QCD shower

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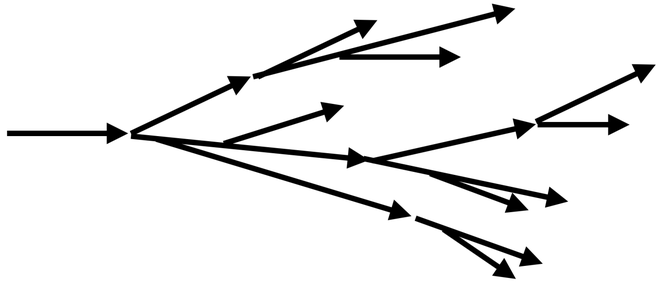
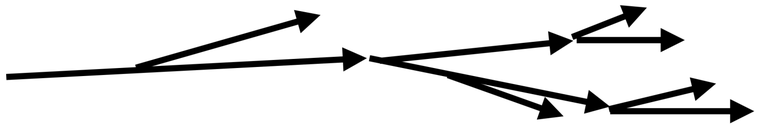
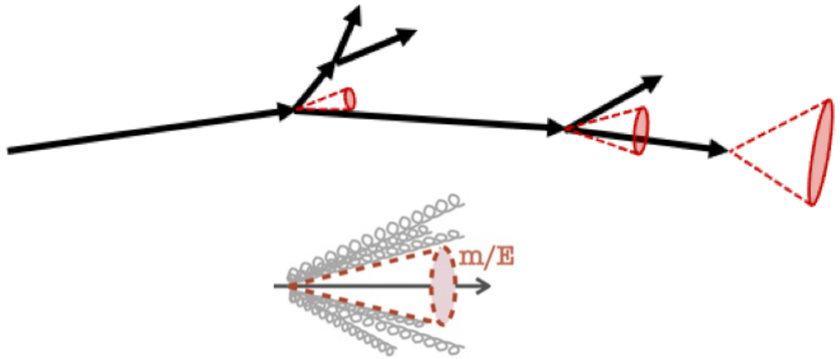


Quark-initiated shower



Heavy-quark-initiated shower



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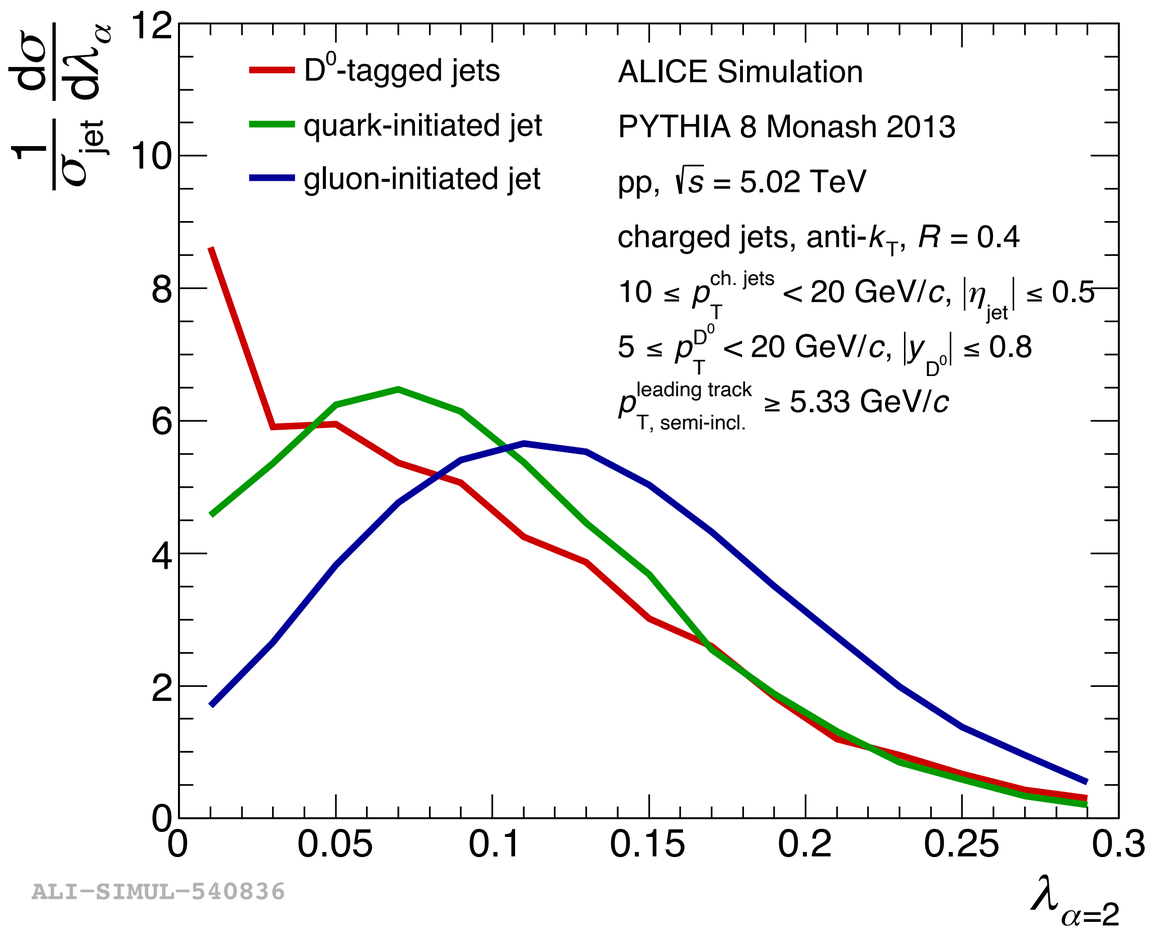
Casimir color factors

Gluon-initiated showers are expected to have a broader and softer fragmentation profile than quark-initiated showers

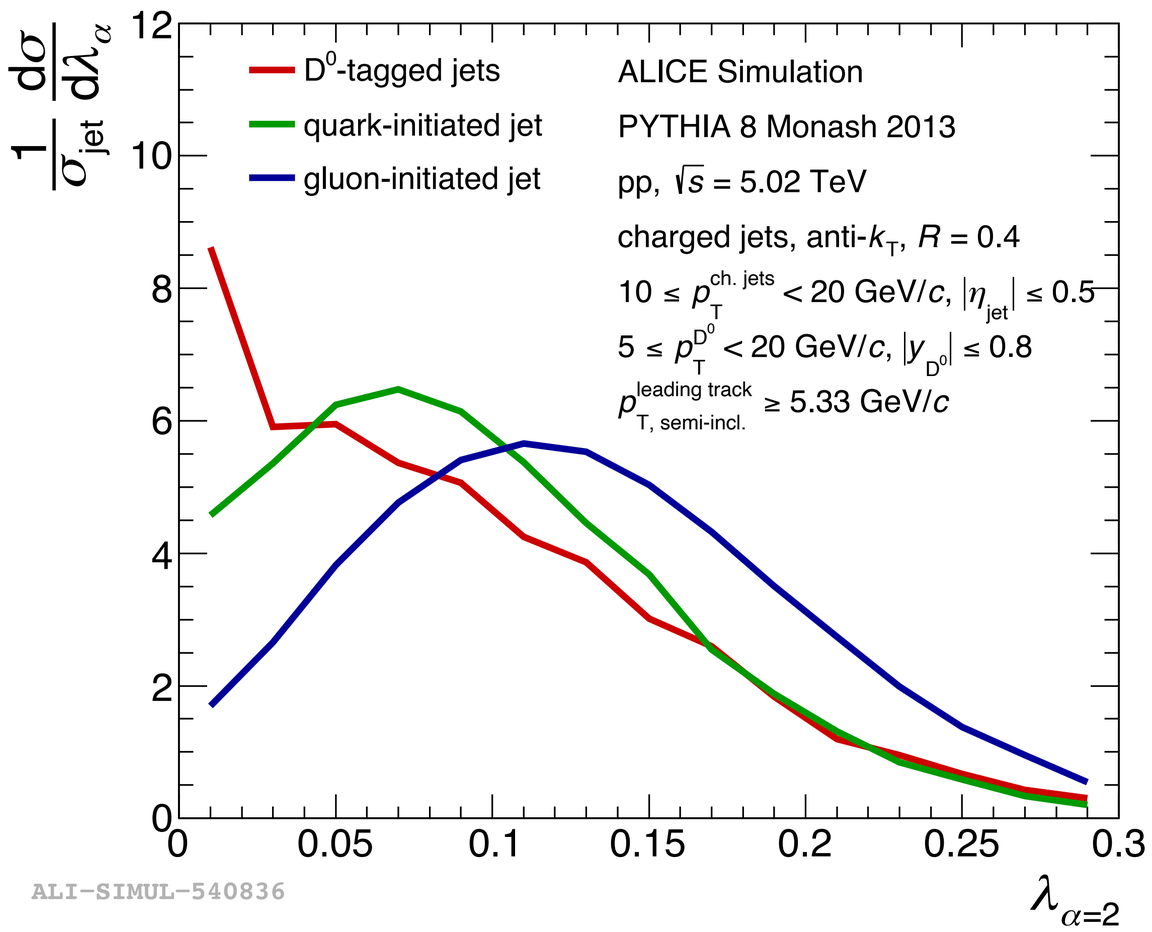
Mass effects

A harder fragmentation is expected in low energy heavy-quark initiated showers due to the presence of a dead cone which suppresses radiation close to the heavy-quark

Flavour dependence in the QCD shower



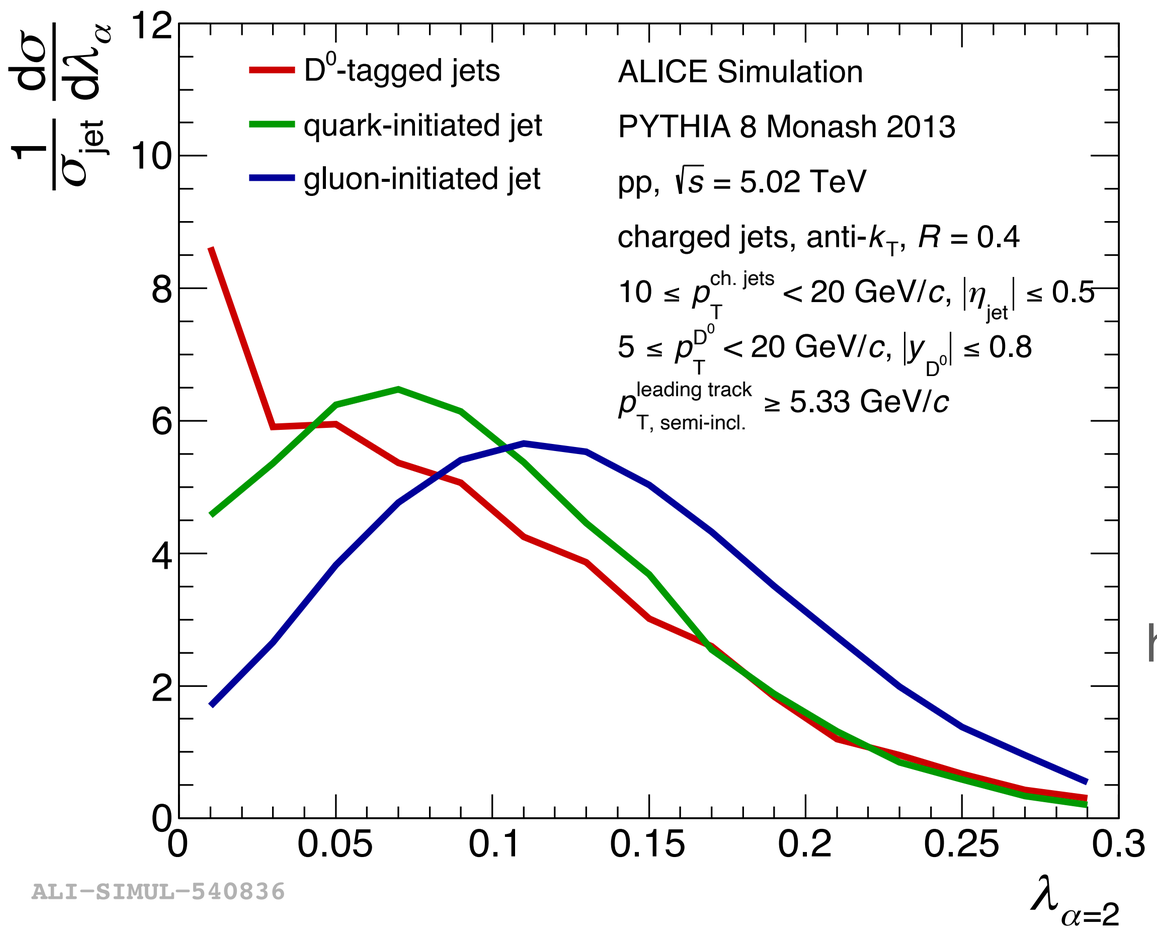
Flavour dependence in the QCD shower



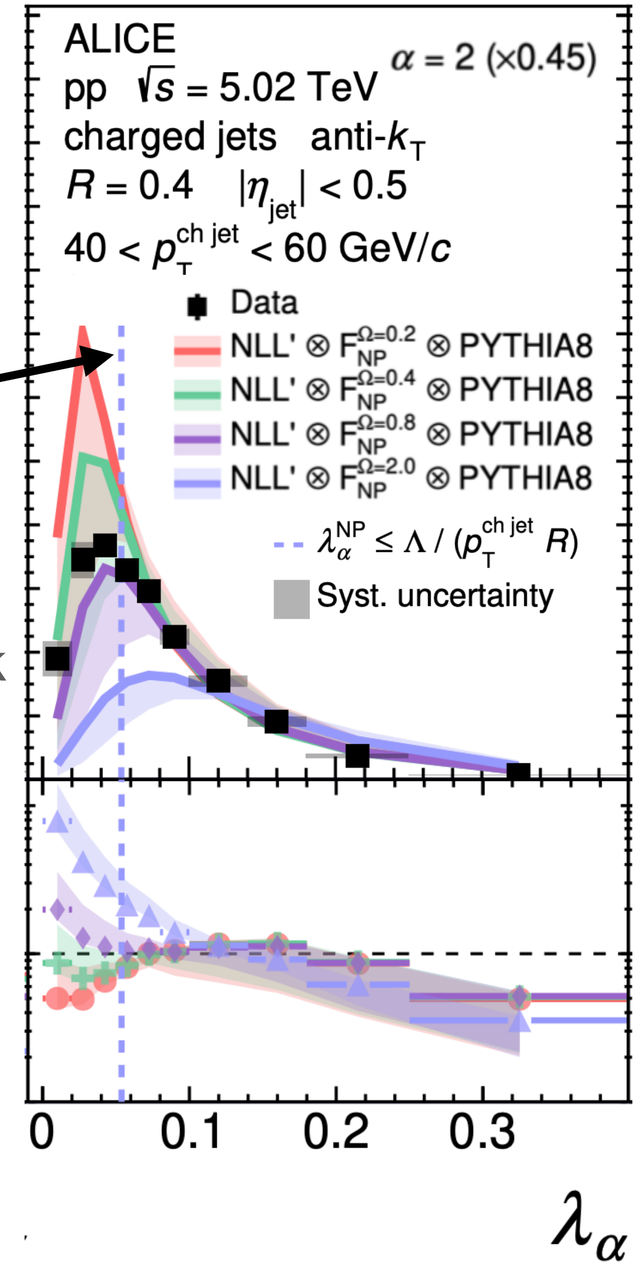
ALI-SIMUL-540836

- The jet angularities are sensitive to flavor dependences in shower
- Charm-tagged jets are quark enriched and comparisons to quark-initiated jets isolates mass effects

Flavour dependence in the QCD shower



JHEP05 (2022) 061

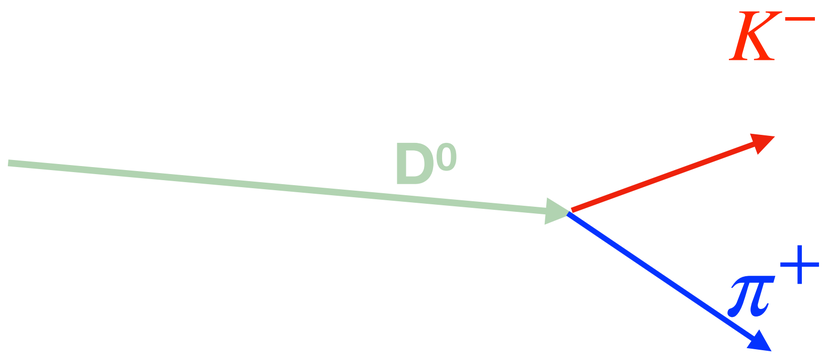


Can we reduce the impact of non-perturbative effects at low jet p_T by adding the extra hard scale of the charm-quark mass?

- The jet angularities are sensitive to flavor dependences in shower
- Charm-tagged jets are quark enriched and comparisons to quark-initiated jets isolates mass effects

Reconstructing D^0-tagged jets

$$D^0 \rightarrow K^- + \pi^+$$



$$2 \leq p_{T,D^0} \leq 36 \text{ GeV}/c$$

D^0 -meson selection:

- topological cuts on the D^0 decay
- particle ID on decay daughters

Reconstructing D⁰-tagged jets

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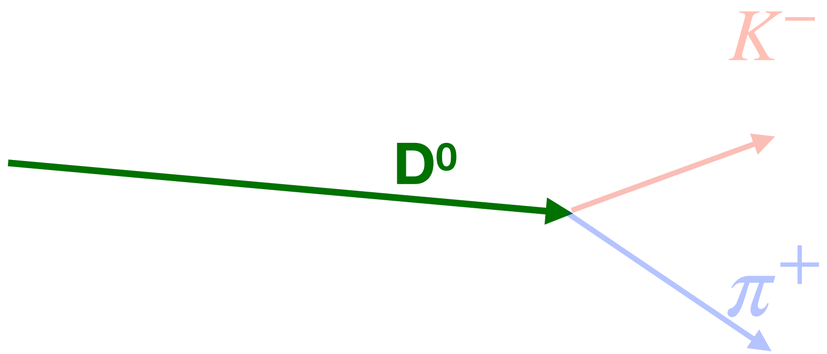

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$K^{\mp}\pi^{\pm}$ pairs replaced by D⁰ candidate

- Full D⁰ momentum always inside the jet cone

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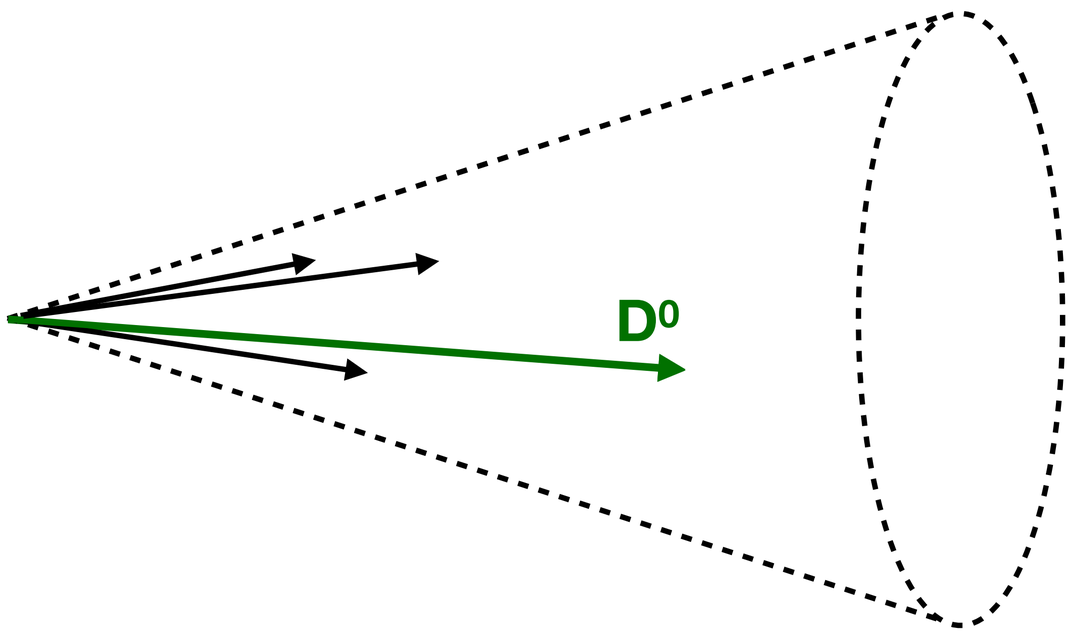


$2 \leq p_{\mathrm{T,D^0}} \leq 36$ GeV/c

$5 \leq p_{\mathrm{T,ch.\ jet}} \leq 50$ GeV/c

D^0 -meson selection:

- topological cuts on the D^0 decay
- particle ID on decay daughters

$K^{\mp}\pi^{\pm}$ pairs replaced by D^0 candidate

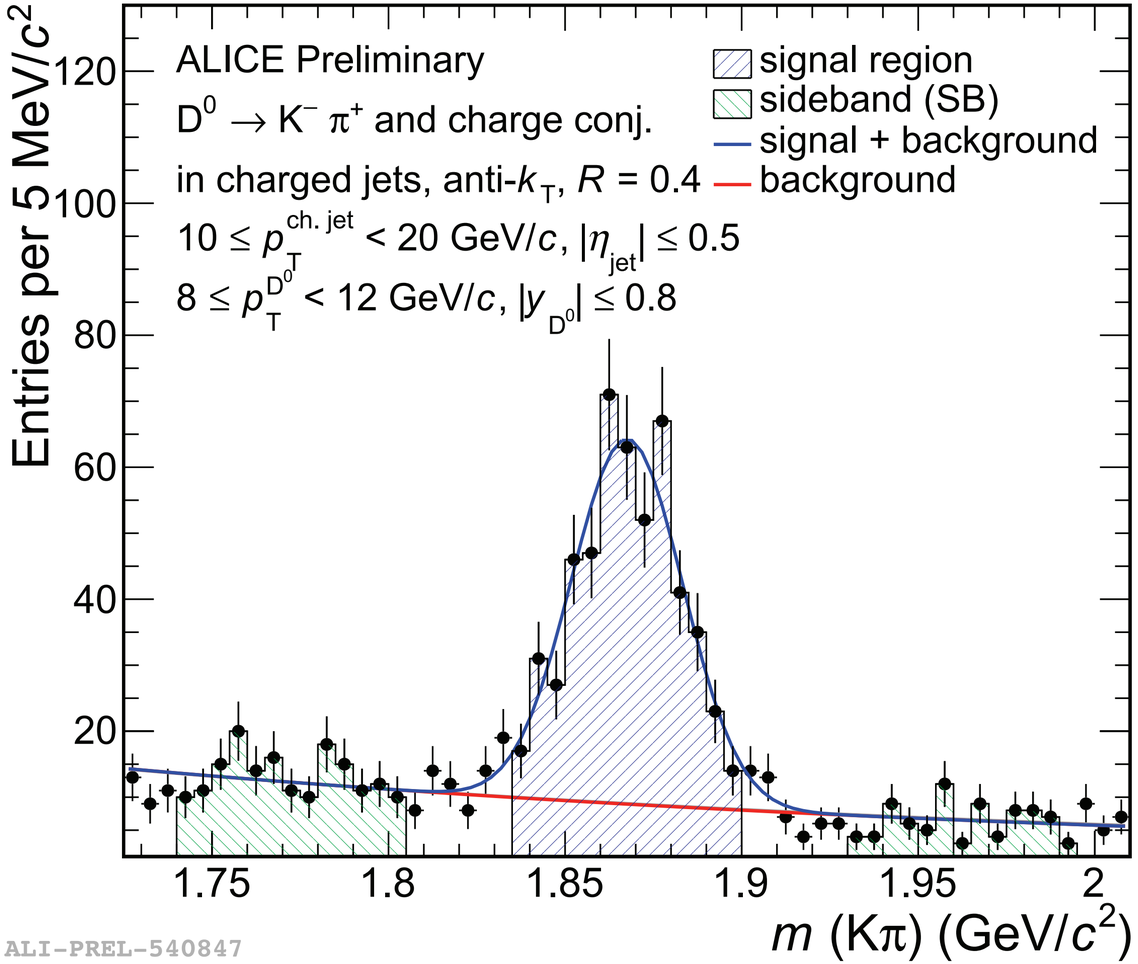
- Full D^0 momentum always inside the jet cone

Jet finding:

- performed independently for each D^0 candidate
- anti-k_T algorithm, $R = 0.4$

→ **D^0-tagged charged jets**

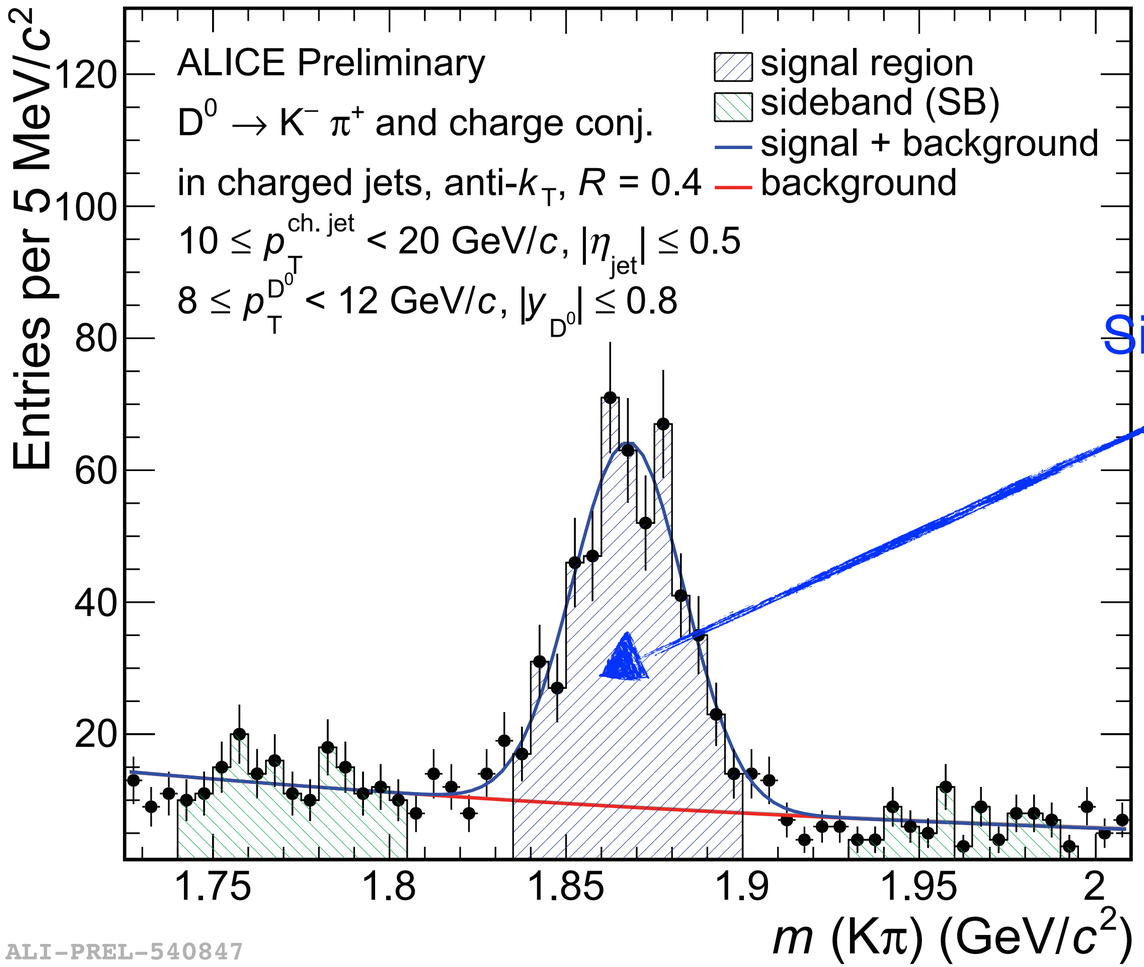
Data-driven signal extraction



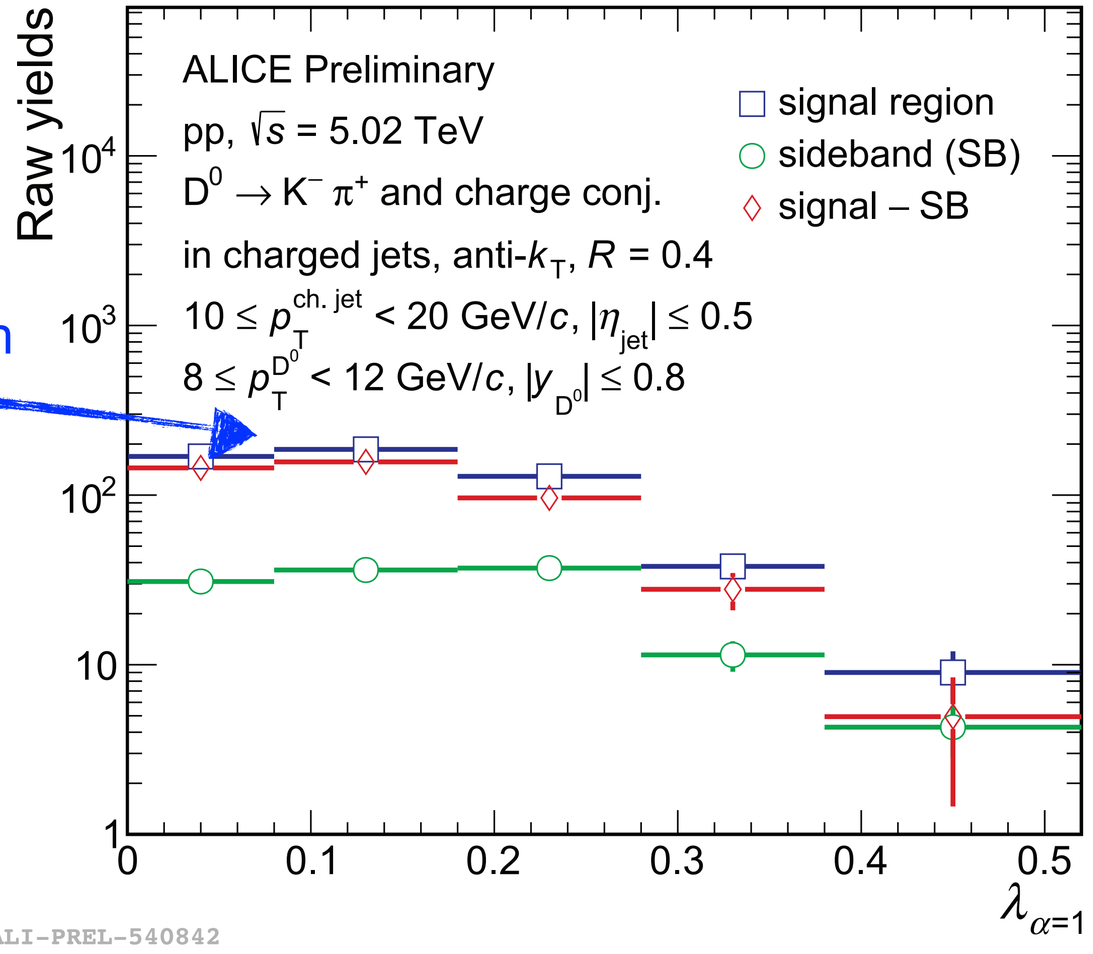
ALI-PREL-540847

- Some combinatorial Kπ pairs pass the D^0 selections
  - Removed via a sideband subtraction method

Data-driven signal extraction



Signal region



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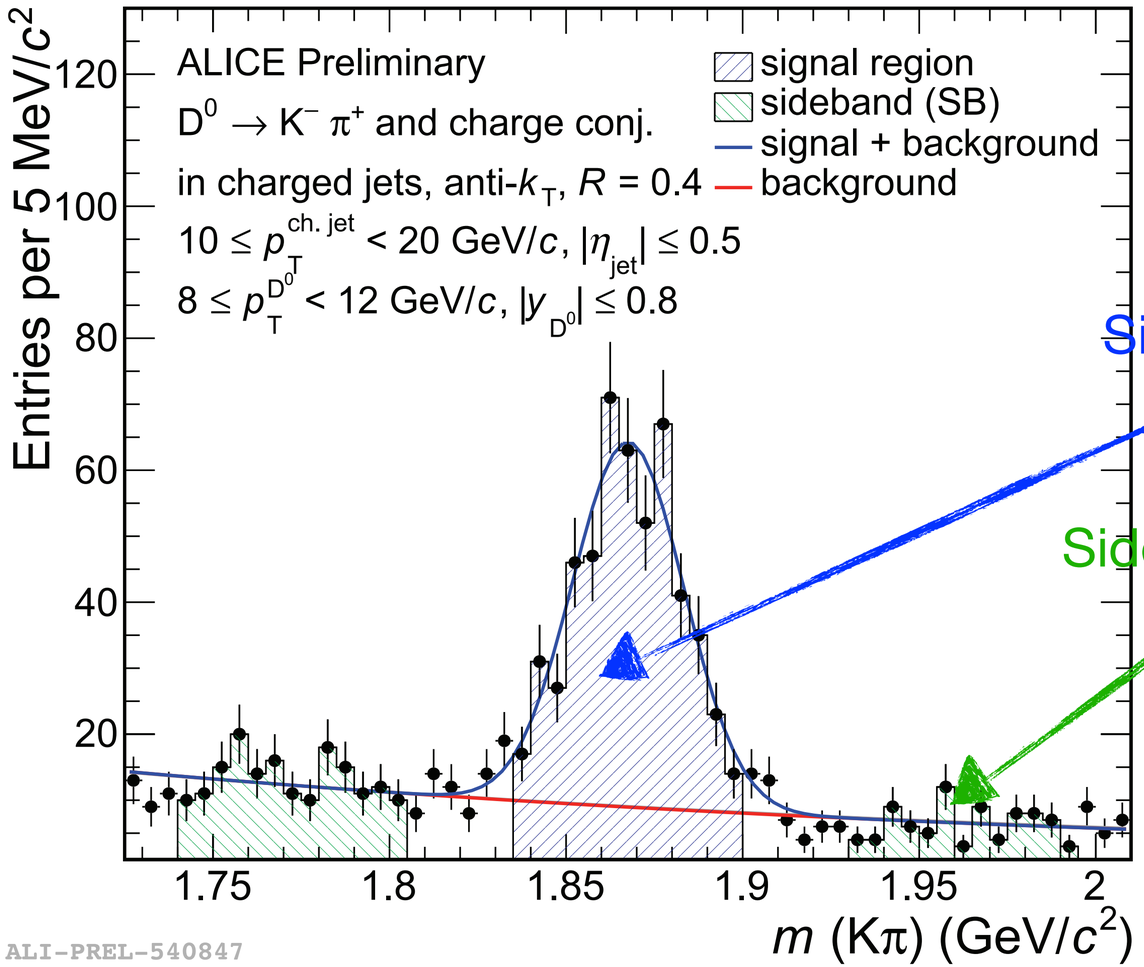
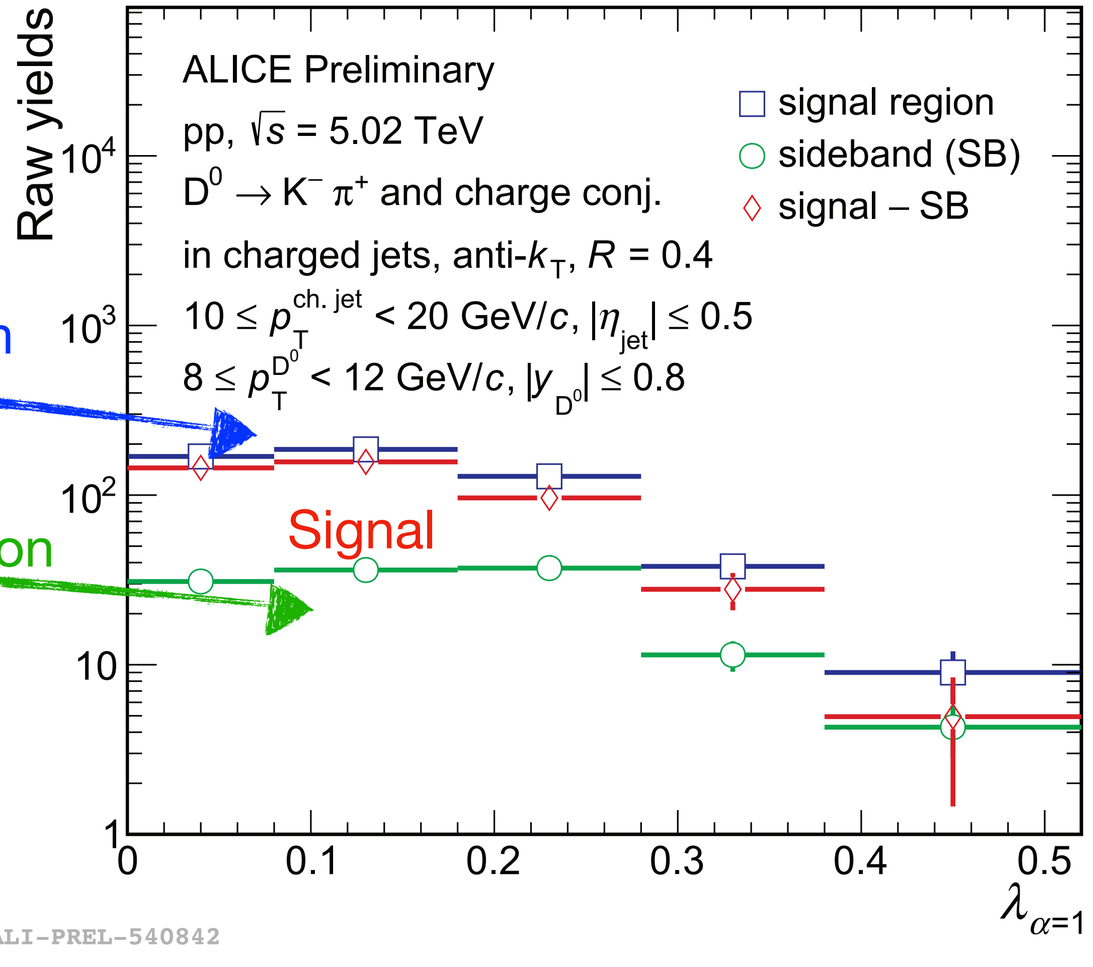


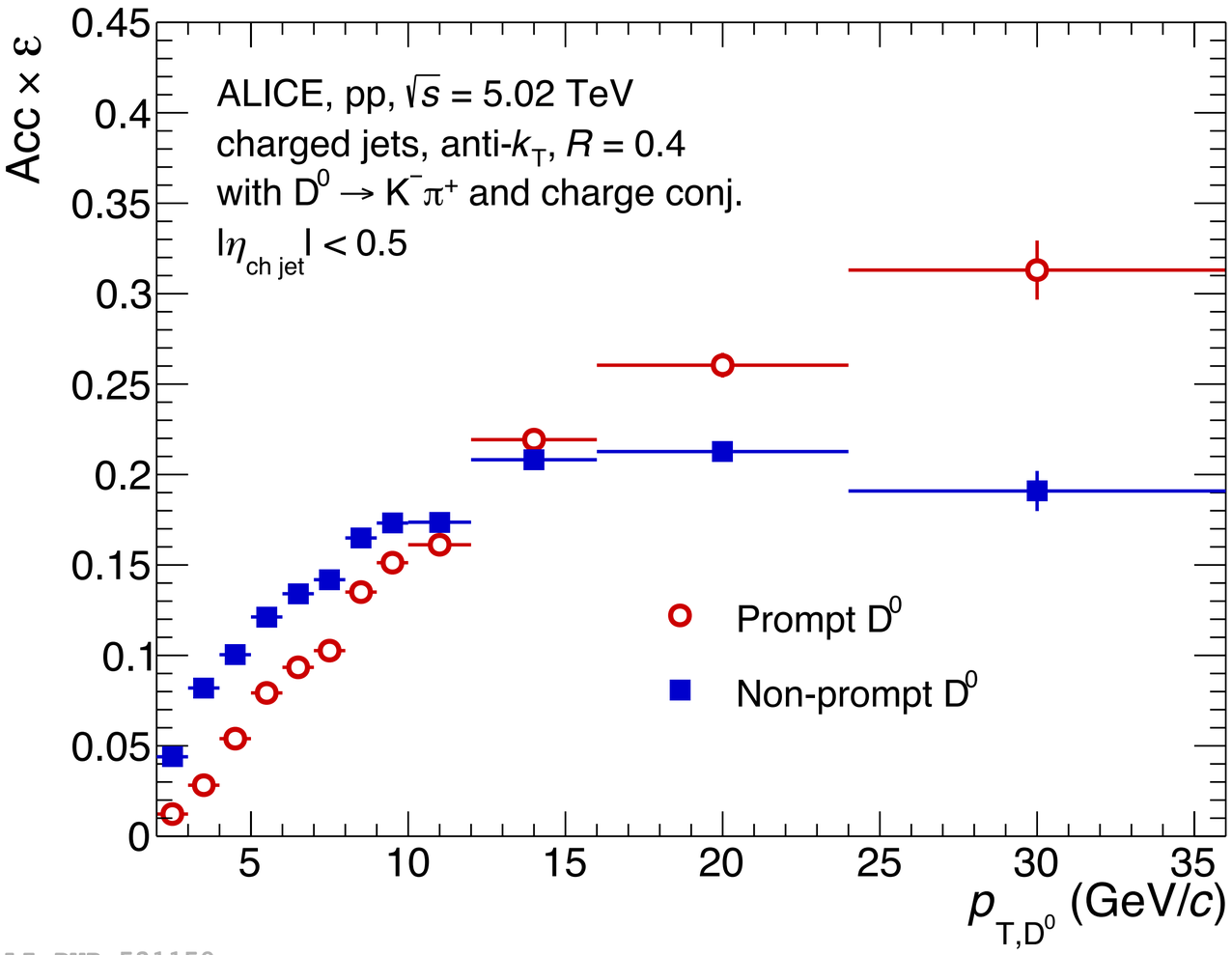
Signal region

Sideband region



- Some combinatorial Kπ pairs pass the D^0 selections
  - Removed via a sideband subtraction method
- Extraction performed in D^0-meson p_T intervals

D⁰ reconstruction efficiency correction

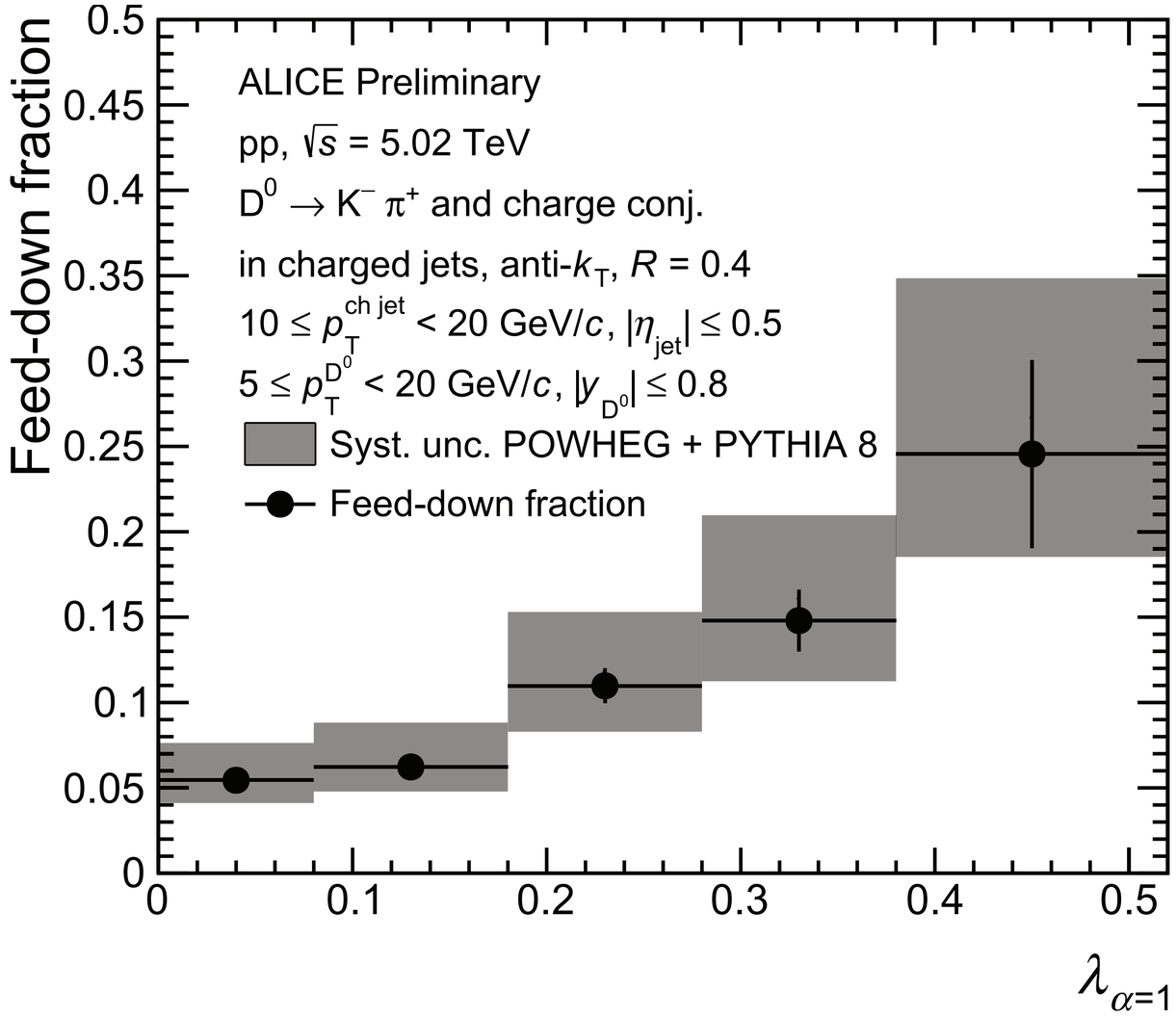


ALI-PUB-521159

- Efficiency of the D⁰ cut selections is strongly dependent on D⁰-meson p_T
- sideband-subtracted distributions are corrected by the D⁰ reconstruction and selection efficiency in narrow D⁰ p_T intervals
- Efficiency-corrected angularity distributions are integrated over D⁰ p_T intervals

Prompt efficiency (c→D⁰) correction

Correcting angularities for $B \rightarrow D^0$ decays

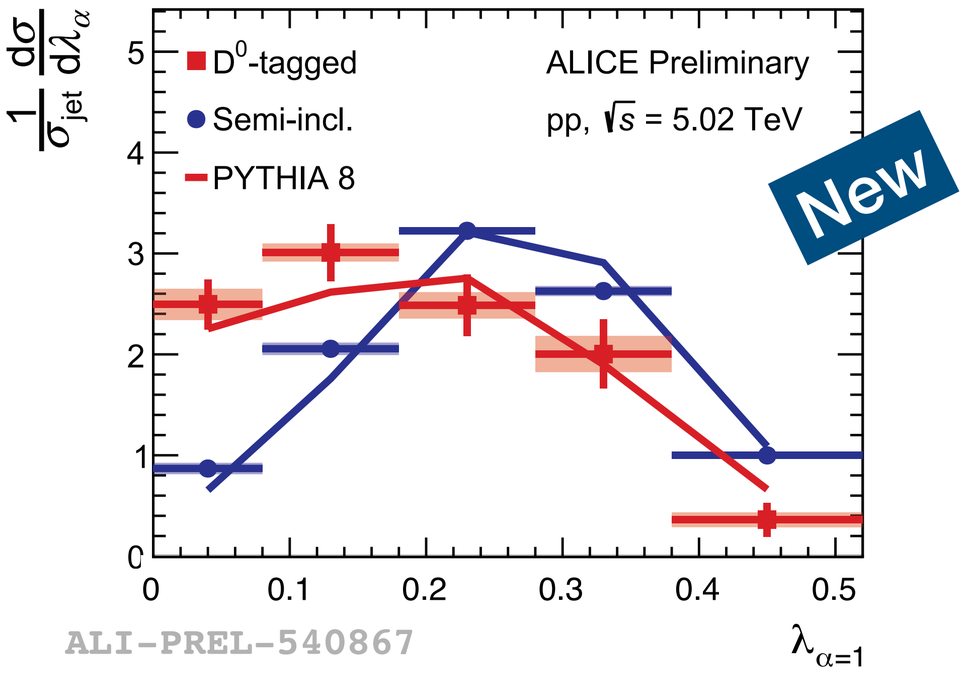


ALI-PREL-540860

- Beauty feed-down contribution estimated using POWHEG + PYTHIA 8.
- Simulation distribution corrected for non-prompt D^0 reconstruction efficiency and folded to detector level
- The presence of additional track from $B \rightarrow D^0$ decays pushes the angularity to larger values for non prompt D0-tagged jet.

Feed-down subtraction (b →D0)

D^0-tagged vs. semi-inclusive jet angularity

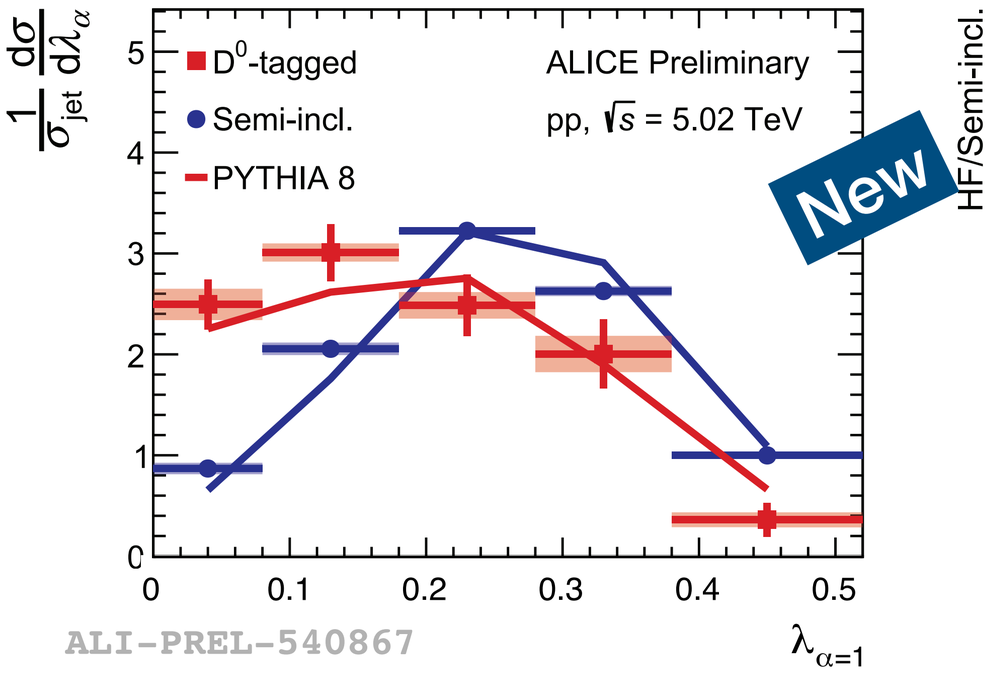


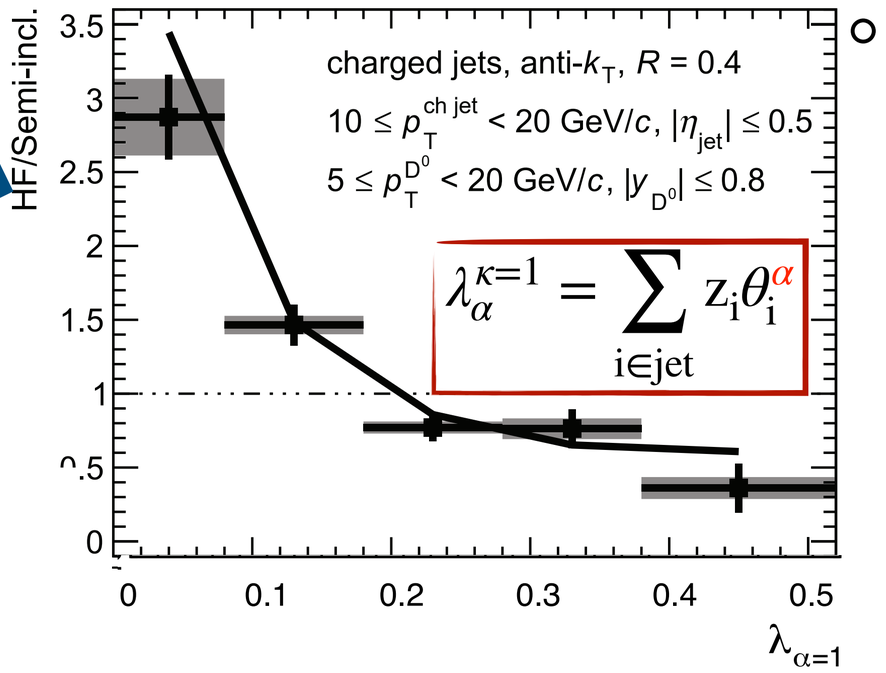
$$\lambda_\alpha^{\kappa=1} = \sum_{i \in jet} z_i \theta_i^\alpha$$

- Fully unfolded measurement

- Semi-inclusive baseline requires $p_T > 5.33$ GeV/c for the leading track
  - Corresponds to transverse mass of a D^0 meson with $p_T = 5$ GeV/c

D⁰-tagged vs. semi-inclusive jet angularity





- **D⁰-tagged jets have lower angularities than semi-inclusive jets**
  - HF jets more ‘collimated’ than semi-inclusive jets
  - Collimation due to:
    - The smaller color charge of quarks compared to gluons
    - The dead cone around the charm quark: charm quark fragments less

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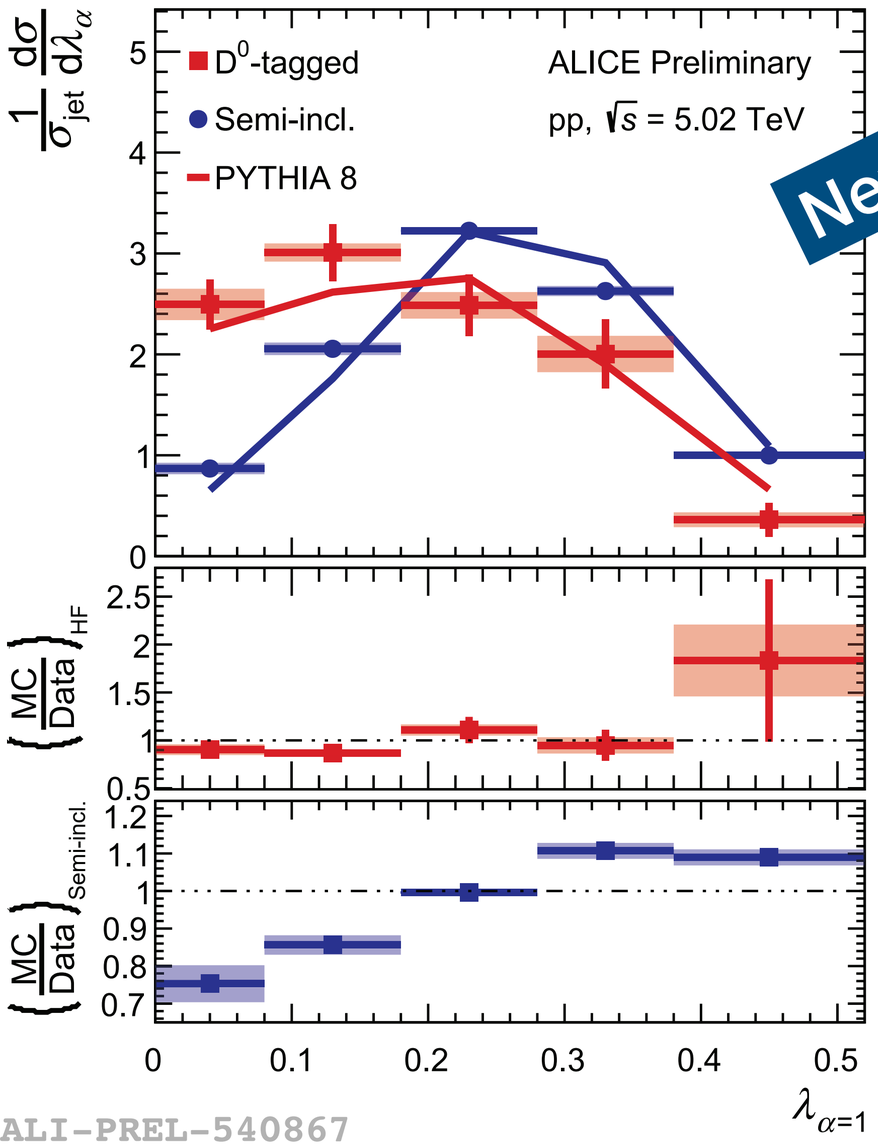
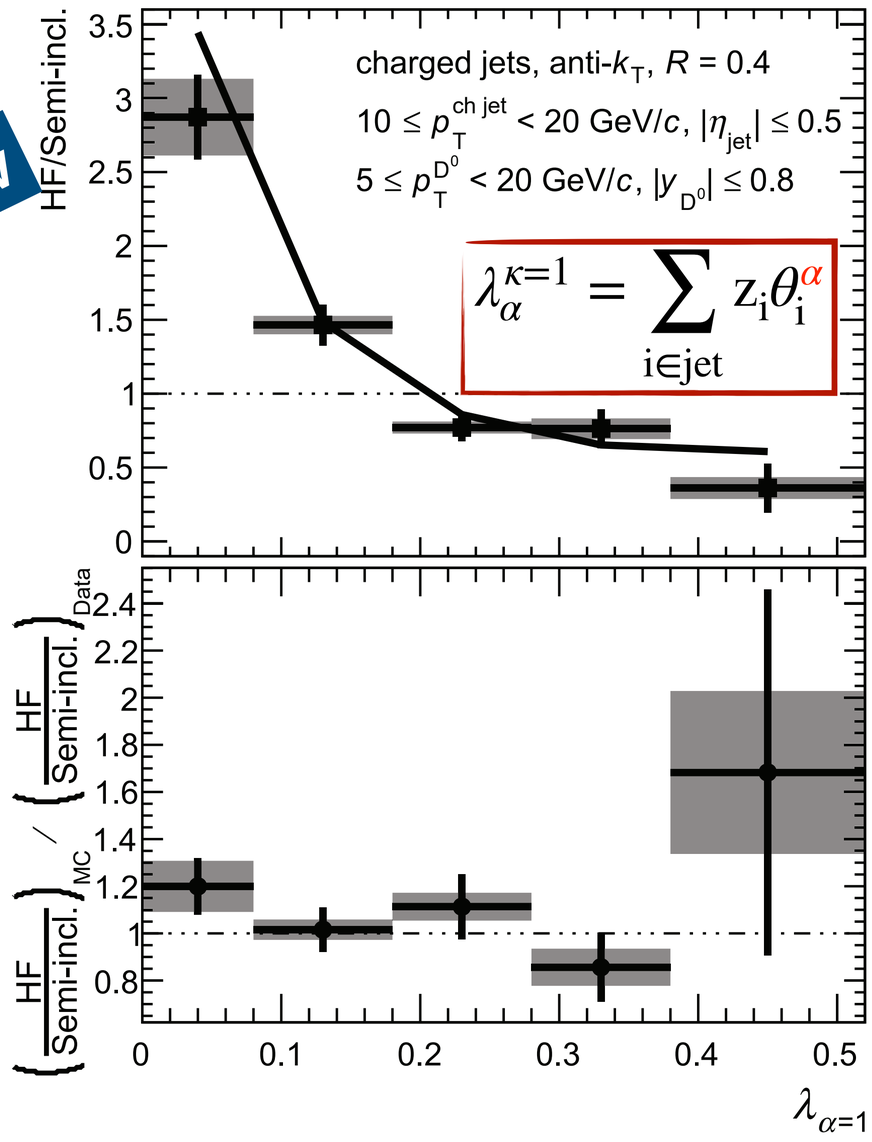


ALI-PREL-540867



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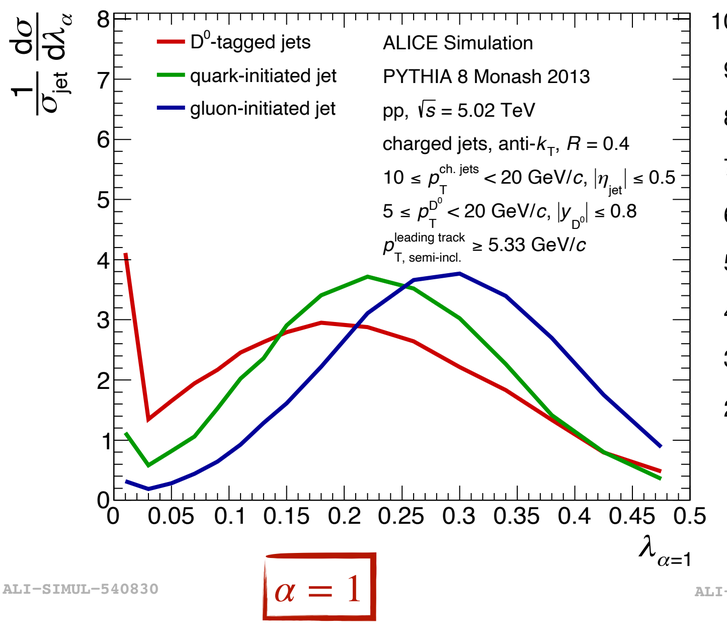
  - HF jets more ‘collimated’ than semi-inclusive jets
  - Collimation due to:
    - The smaller color charge of quarks compared to gluons
    - The dead cone around the charm quark: charm quark fragments less
- Do PYTHIA simulations do a better job of describing charm-tagged jet angularities compared to semi-inclusive?

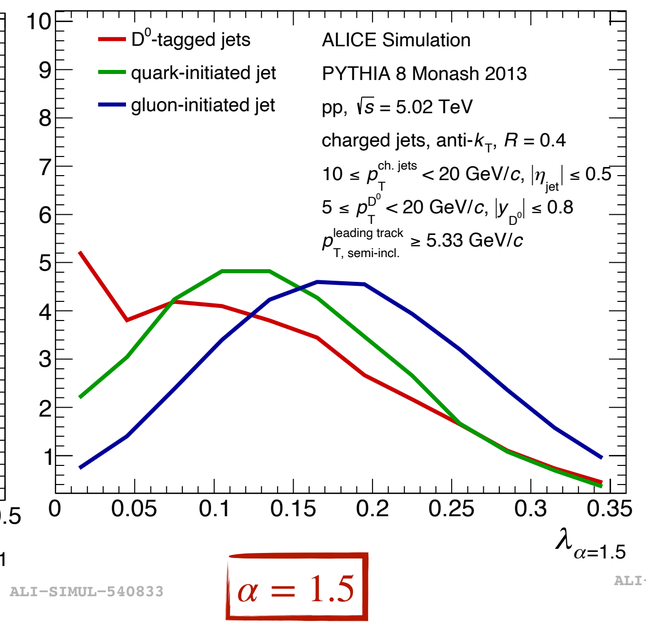
Tuning the flavor dependence by varying alpha

$$\lambda_\alpha^{\kappa=1} = \sum_{i \in jet} z_i \theta_i^\alpha$$

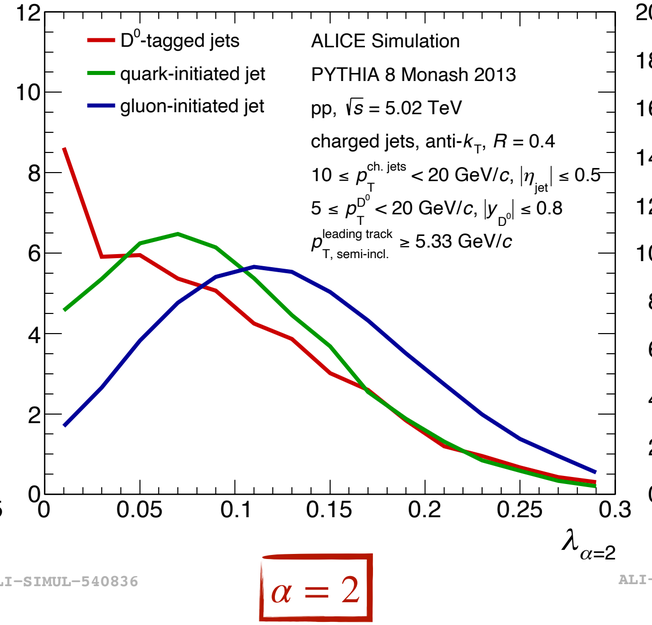
- How much of this modification is due to the D0 jet being a **quark jet** versus being a **HF jet**?



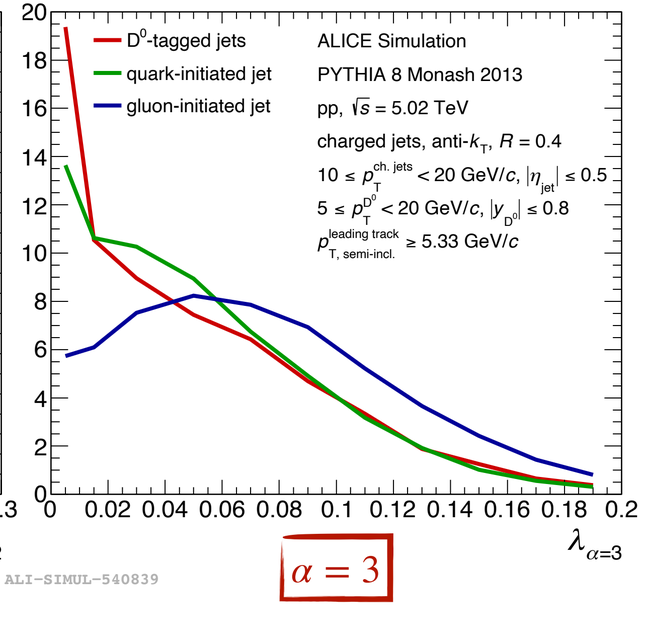
$\alpha = 1$



$\alpha = 1.5$



$\alpha = 2$



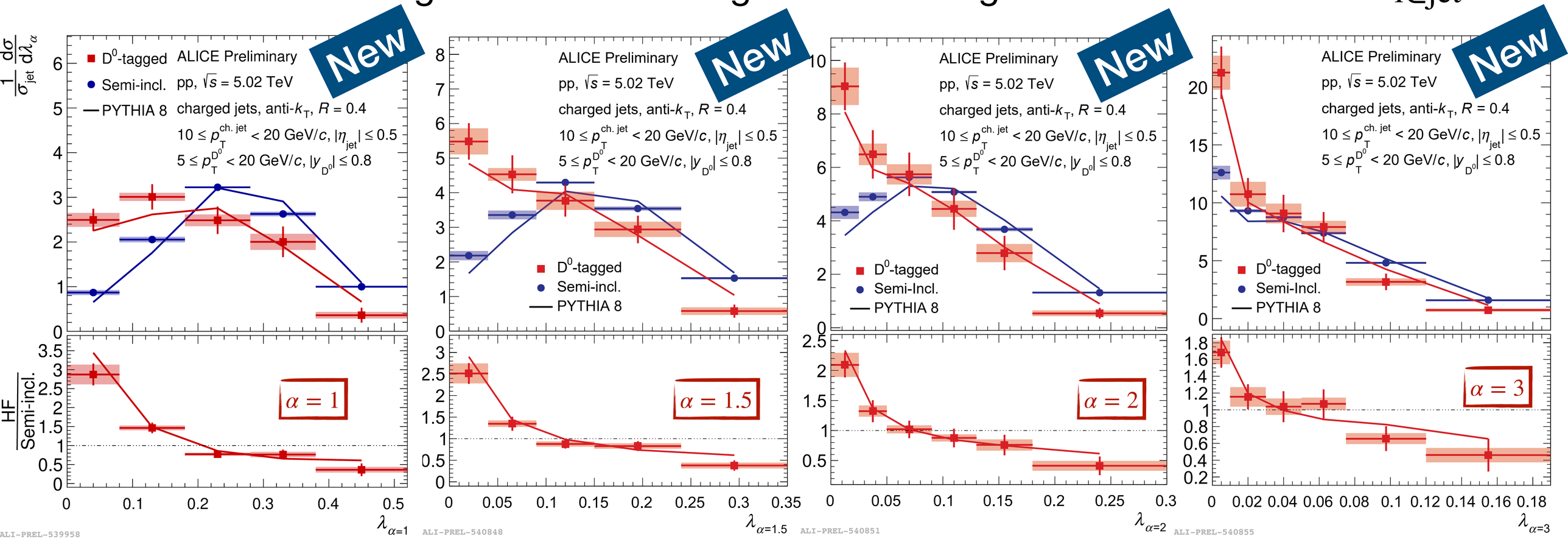
$\alpha = 3$

- With increasing α the impact of mass effects is reduced : D0-tagged and quark-initiated distributions become more similar → cleaner sensitivity to Casimir colour effects
- At lower α where the core of the jet has a higher weight → large angle radiation has a lower weight, mass effects are more prominent

Scanning the angular profile of jets

$$\lambda_\alpha^{\kappa=1} = \sum_{i \in jet} z_i \theta_i^\alpha$$

Higher α →more weight on wide angle emissions



- With increasing α the shape of the charm-tagged and semi-inclusive angularities begin to converge

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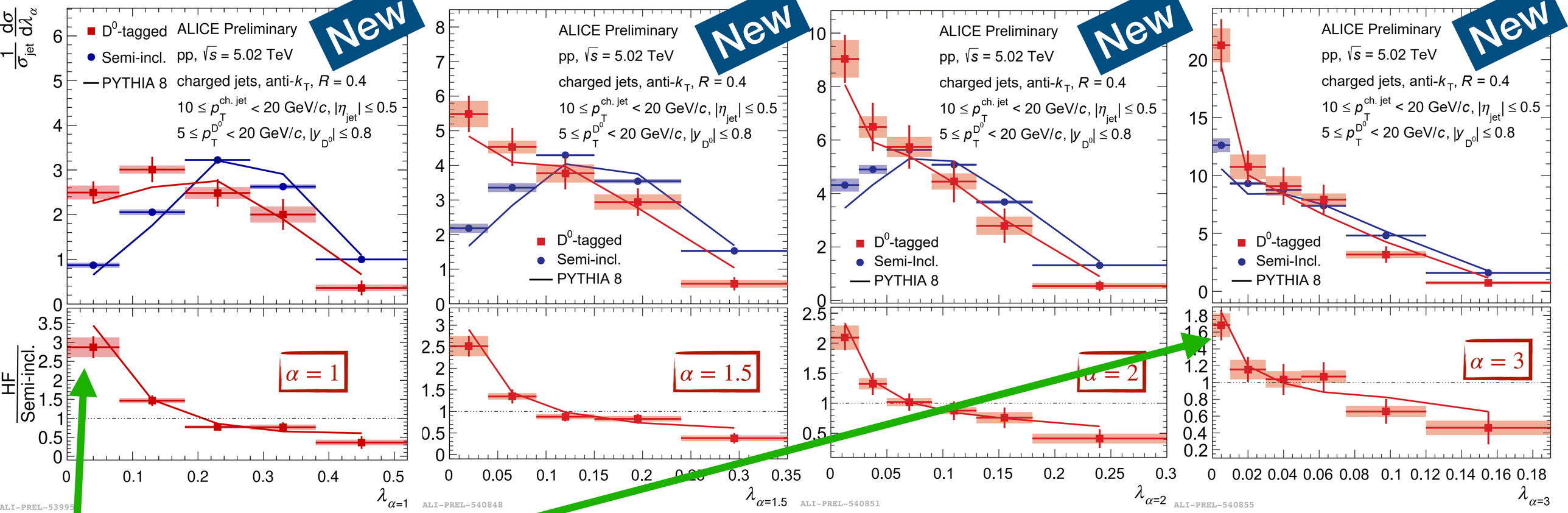
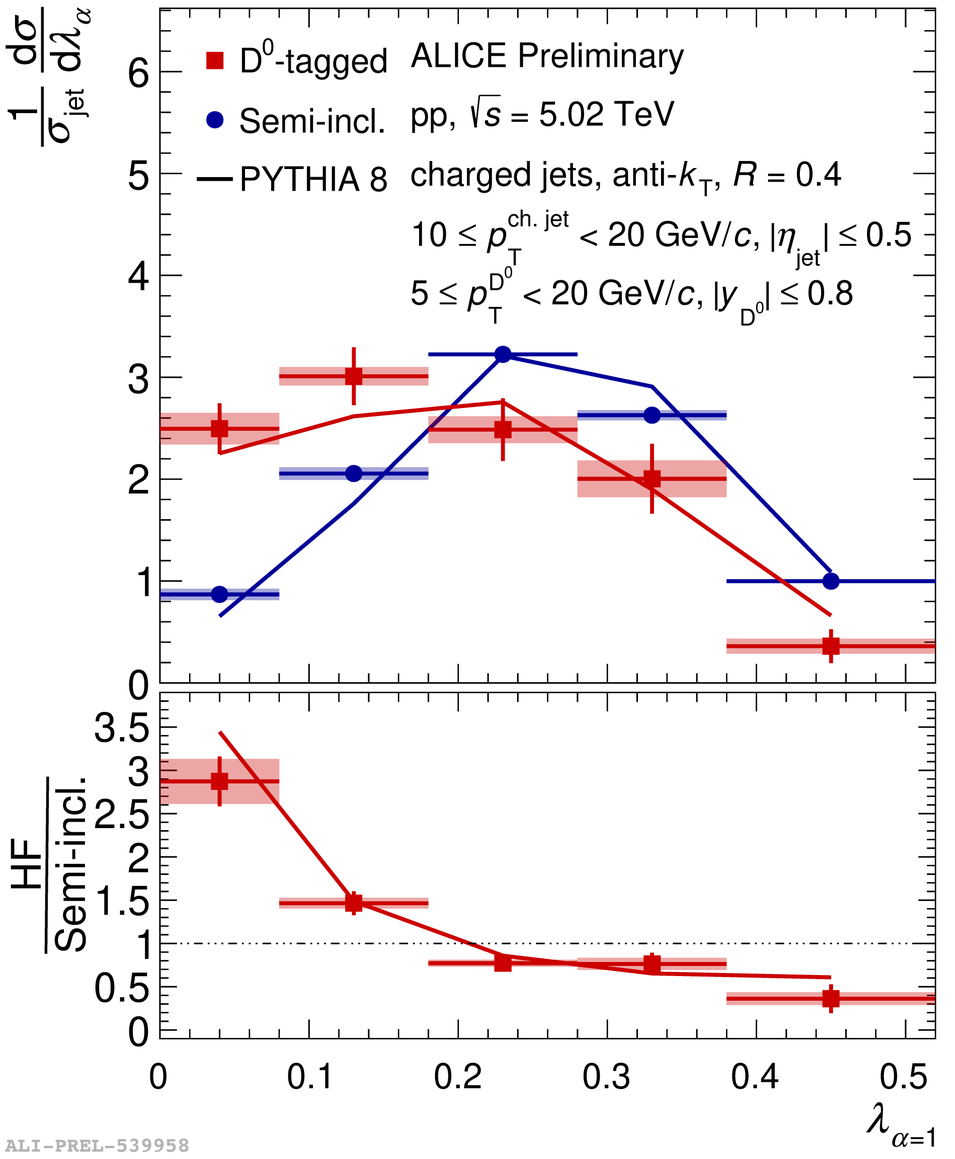


- With increasing α the shape of the charm-tagged and semi-inclusive angularities begin to converge
- Suggests that the largest differences are in the jet core arising from mass effects

Summary

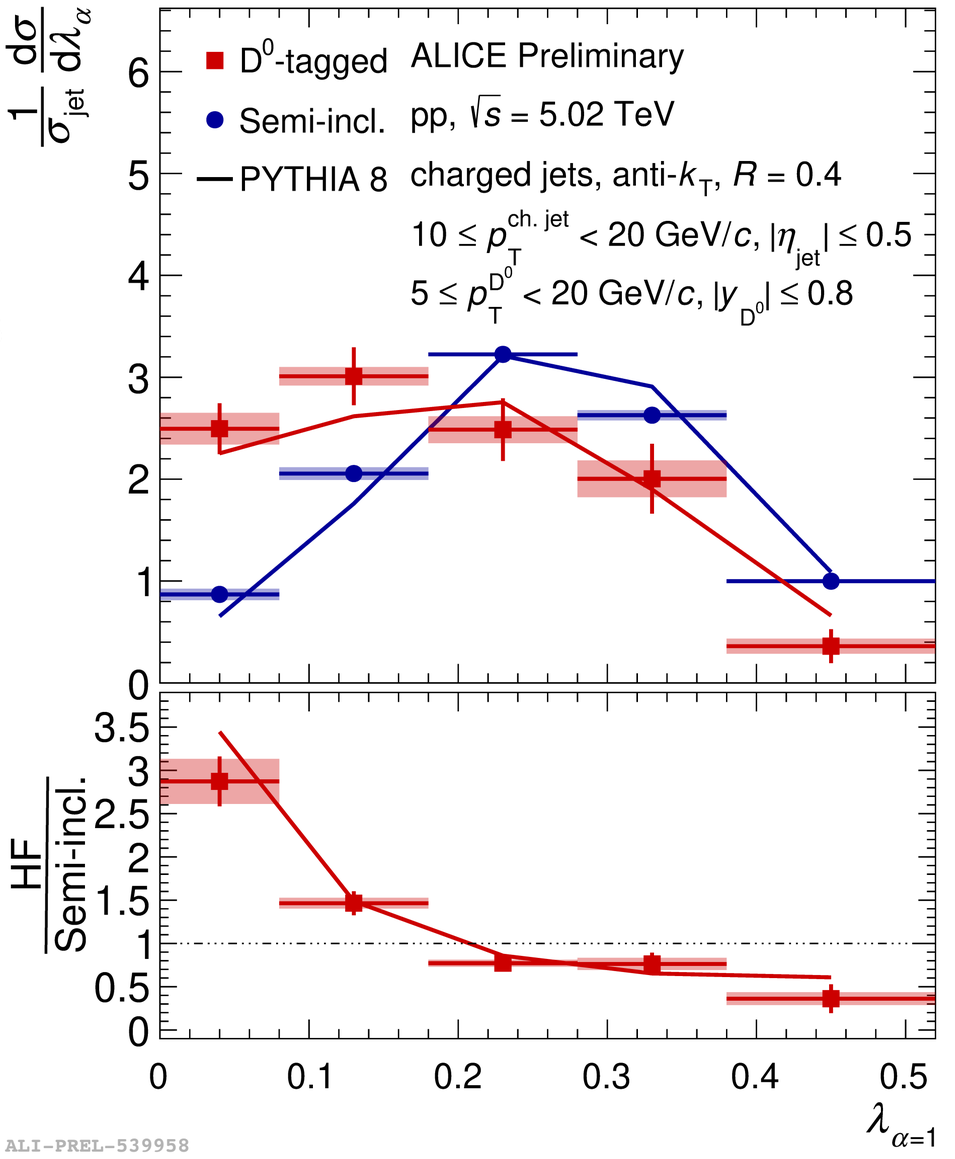
- First measurement of angularities of charm-quark showers using D^0-tagged jets



Summary

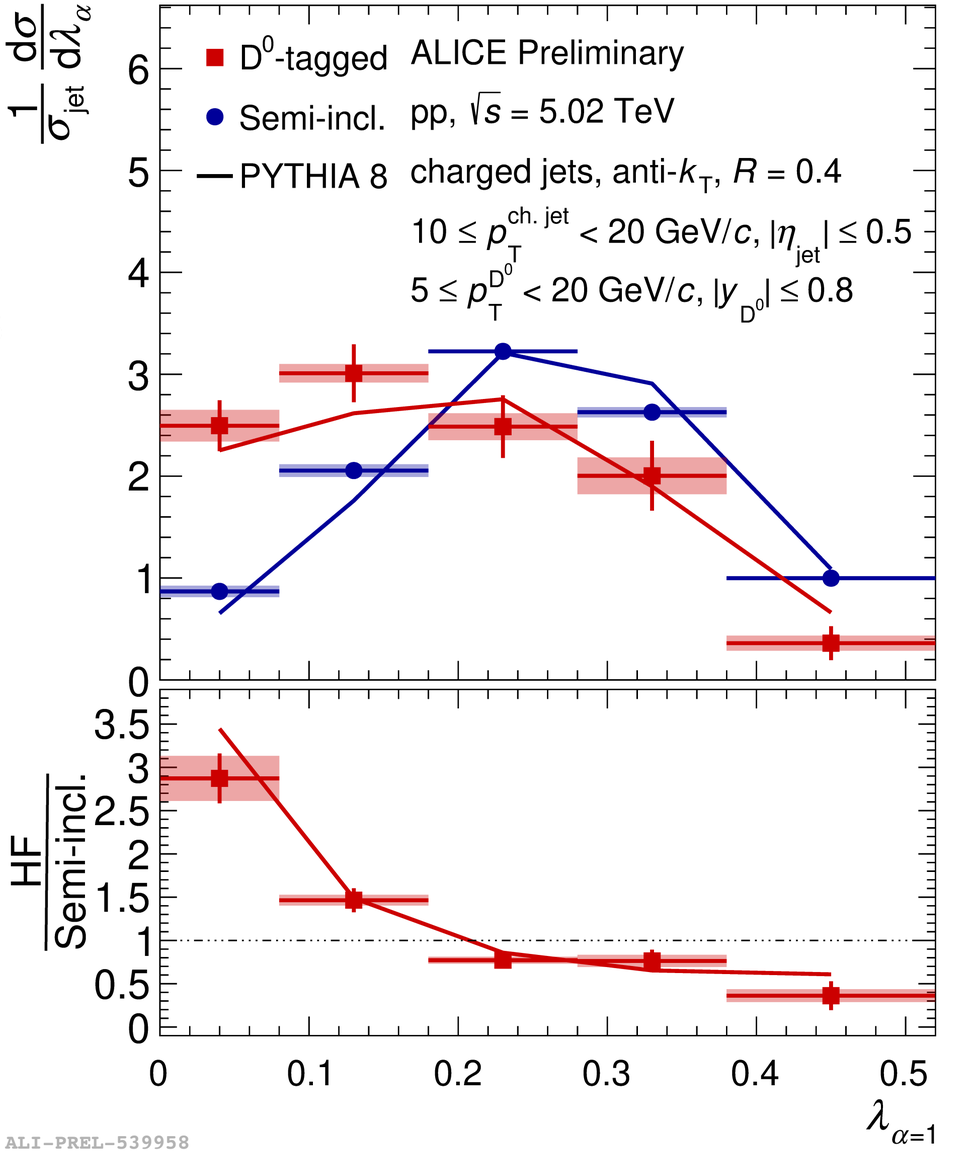
- First measurement of angularities of charm-quark showers using D^0-tagged jets

- Comparisons of D^0-tagged and semi-inclusive jets is sensitive to both mass and Casimir color effects in the shower



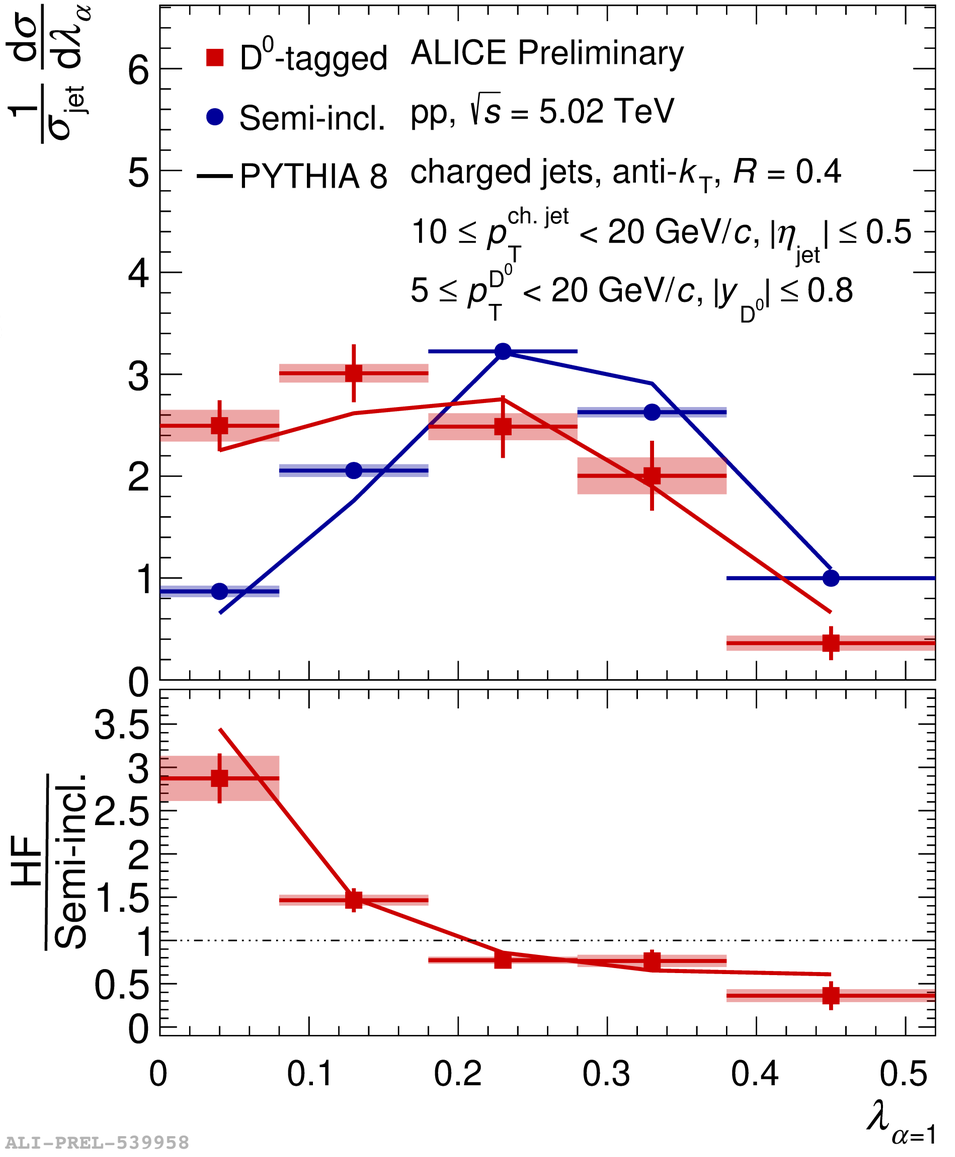
Summary

- First measurement of angularities of charm-quark showers using D^0-tagged jets
- Comparisons of D^0-tagged and semi-inclusive jets is sensitive to both mass and Casimir color effects in the shower
- Scanning through different α parameters can control the impact of each of the flavor effects



Summary

- First measurement of angularities of charm-quark showers using D^0-tagged jets
- Comparisons of D^0-tagged and semi-inclusive jets is sensitive to both mass and Casimir color effects in the shower
- Scanning through different α parameters can control the impact of each of the flavor effects
- D^0-tagged jets have narrower angularities than semi-inclusive jets, with the distribution shapes becoming more similar at large values of α



Backup slides

ALICE talks

Measurement of the jet mass and jet angularities in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$= 5.02 TeV.

→Talk by **Ezra Lesser** yesterday at 17:10.

First measurements of in-jet fragmentation and correlations of charmed mesons and baryons in pp collisions with ALICE

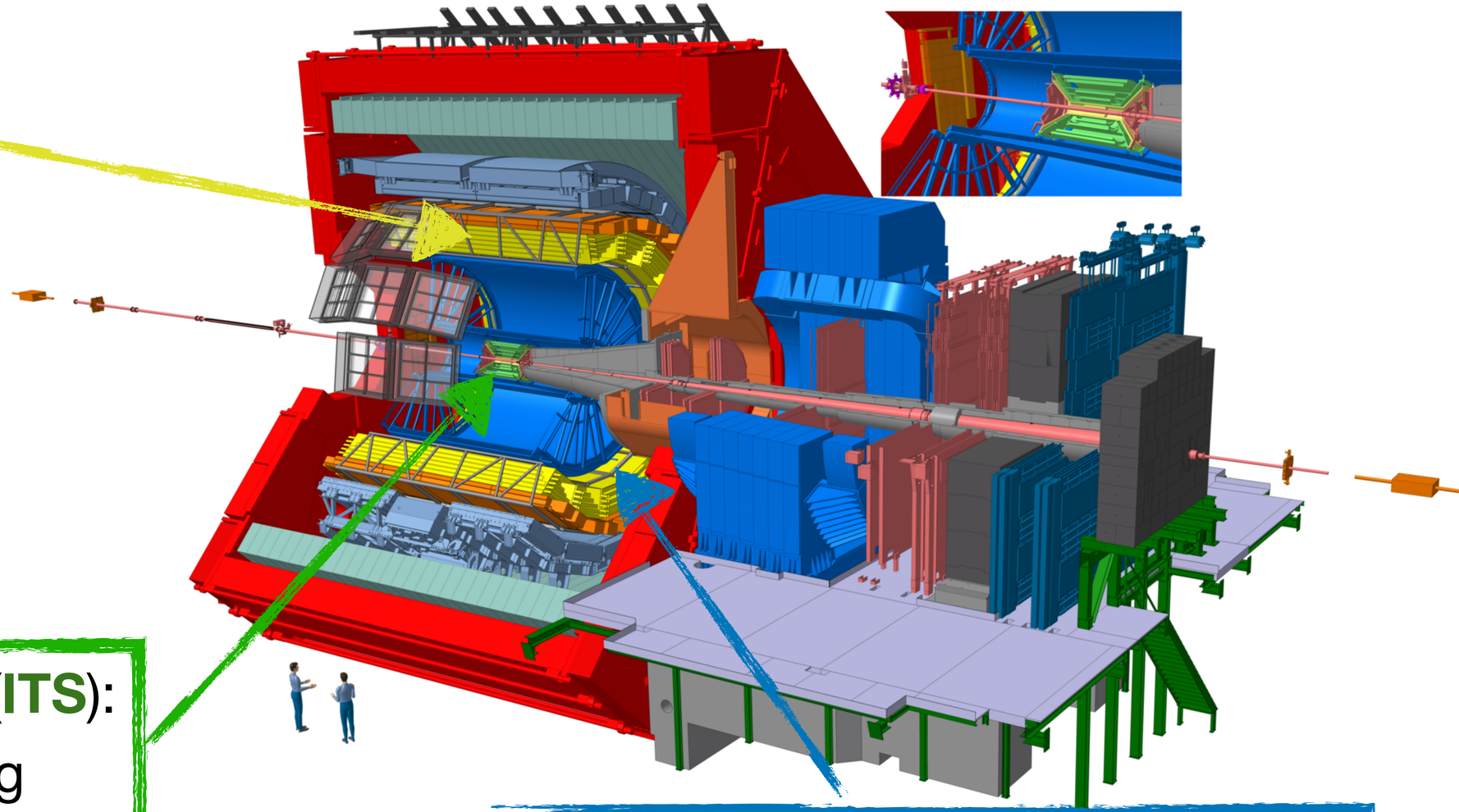
→Talk by **Antonio Palasciano** today at 14:40.

Measurement of the angle between jet axes and energy-energy correlators with ALICE

→Talk by **Reynier Cruz-Torres** yesterday at 17:50.

A Large Ion Collider Experiment

Time-Of-Flight (**TOF**):
PID via time of flight



Inner Tracking System (**ITS**):
tracking and vertexing

Time Projection Chamber (**TPC**):
tracking and PID via d*E*/d*x*