Probing the shower properties of charm quarks using energy-energy correlators with ALICE

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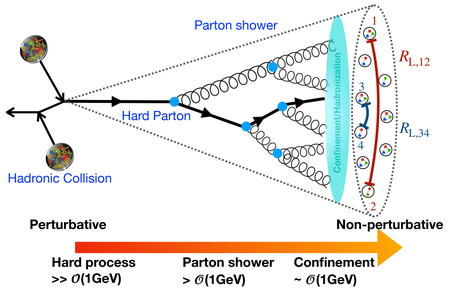
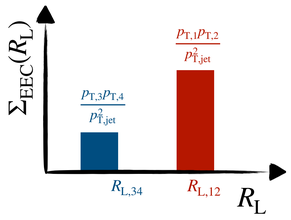
I. Unravel different QCD scales with jet substructure

- Jets probe a wide range of interaction Q^2
- QCD emissions in parton showers are angular ordered. The early splittings (perturbative) are wider ($R_{L,12}$) and the late splittings (non-perturbative) are narrower ($R_{L,34}$)



II. What are the energy-energy correlators (EECs)?

- EEC jet substructure observable: how is energy distributed within a jet?
- Derived from quantum field theory, & IRC-safe observable → precise theoretical calculations



Calculating the Σ_{EEC} observable

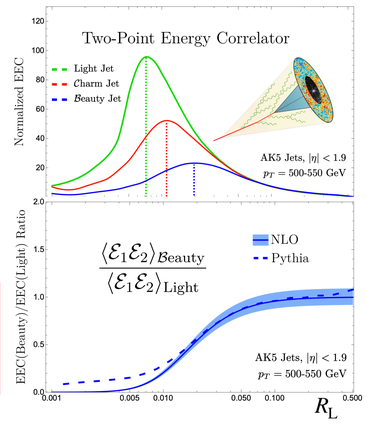
1. Construct anti-k_T jets
2. Calculate the energy weight $(p_{T,i}p_{T,j}/p_{T,jet})$ for each pair (i,j) of tracks inside the jet.
3. Count the number of weighted track pairs as a function of R_L

$$\Sigma_{EEC}(R_L) = \frac{1}{N_{jet}} \sum_N \int \sum_{i,j} dR'_L \frac{p_{T,i}p_{T,j}}{p^2_{T,jet}} \delta(R'_L - R_{L,ij}) \quad \text{where } R_{L,ij} = \sqrt{\Delta\phi^2_{ij} + \Delta\eta^2_{ij}}$$

III. Why are we interested in EECs?

- $\Sigma_{EEC}(R_L)$ probes jet dynamics from perturbative (large R_L) to non-perturbative scales (small R_L).
- Mass effects due to the dead-cone imprinted on angular scale (R_L) and amplitude
- Ratio of heavy to light flavor jet EECs shows large suppression at smaller angles → due to the dead-cone effect

EECs probe detailed structure of QCD radiation from heavy quarks: a precision test of mass-dependent effects in parton showers and hadronization

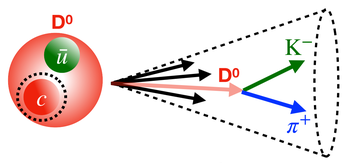


arXiv:2210.09311

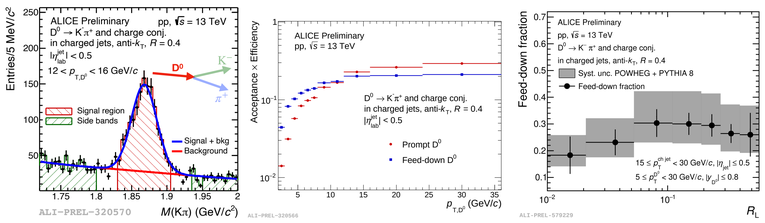
IV. How to measure charm-tagged jet EECs?

1. Reconstruct D^0-meson candidates from decay daughter tracks using topological and particle identification selections

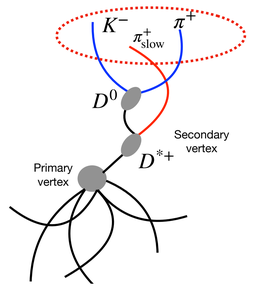
   $D^0 \rightarrow K^- + \pi^+$ and charge conjugate

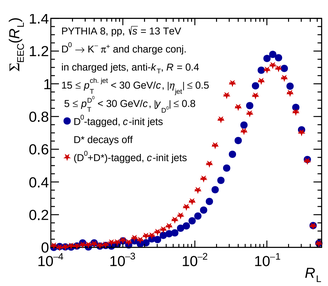


2. D^0-tagged charged jets: anti-k_T jet algorithm (R = 0.4) for each D^0 candidate → calculate $\Sigma_{EEC}(R_L)$
3. **Remove background D^0 candidates** using side-band subtraction

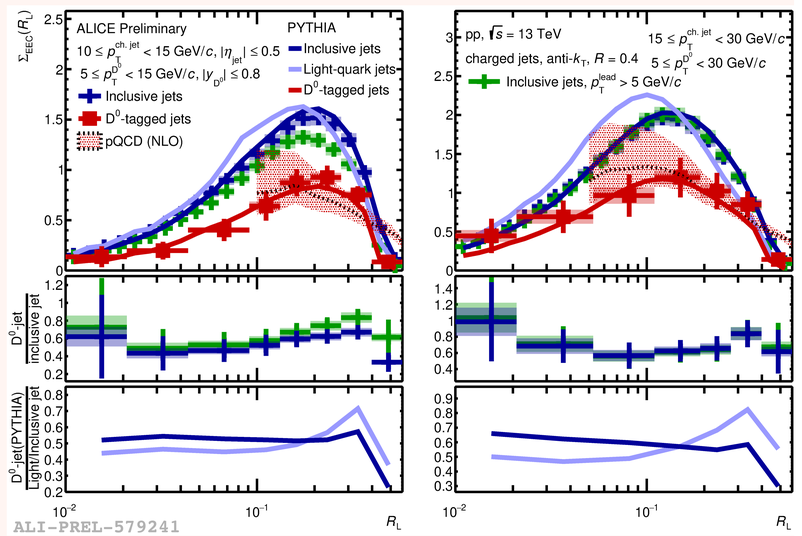


4. **Correct for D^0-tagged jet reconstruction efficiency**
5. **Feed-down correction:** beauty feed-down ($B \rightarrow D^0$) estimation using POWHEG + PYTHIA 8. Corrected for non-prompt D^0 reconstruction efficiency.
6. **Detector effects:** Correct $\Sigma_{EEC}(R_L)$ for track momentum resolution, angular resolution, and both single-track and pair inefficiencies
7. **Removed $D^{*\pm}$ contribution** using the ratio $\frac{D^{*\pm} \text{ decay turned Off}}{D^{*\pm} \text{ decay turned On}}$, calculated from PYTHIA 8 simulations





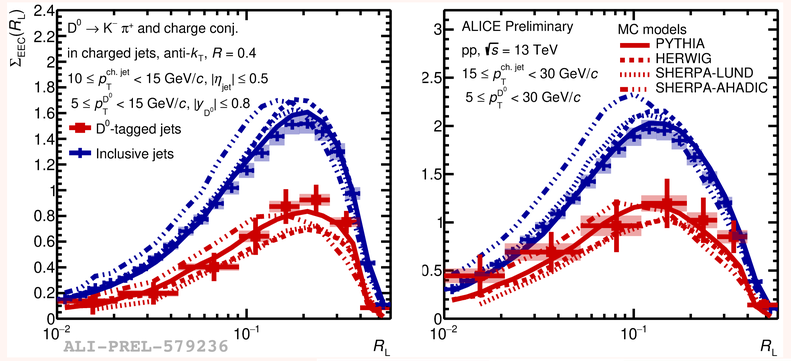
V. Charm-tagged jet EECs



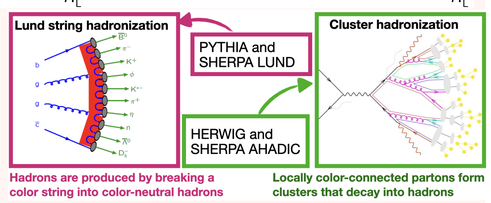
- Charm-tagged jet EECs have a lower amplitude than inclusive jet EECs → expected from the "dead-cone effect"
- Striking peak similarity of charm-tagged and inclusive jet (gluon dominated) → complex interplay: flavor effects in the shower vs. non-perturbative hadronization effects
- Leading particle p_T cut in inclusive jet at low $p_{T,jet}$: bias towards quark-initiated jets → hints at a shift towards light quark-initiated jet MC!
- pQCD calculations reproduce general shape, with some tension near peak → reflects limitations in the treatment of hadronization
- Ratio of charm-tagged to light-quark jets, both quark-initiated, shows significantly more suppression at small angles

Outlook: adding beauty-tagged jets and extending to higher $p_{T,jet}$ with Run 3 data will allow a more systematic study of mass effects in parton shower and hadronization

VI. Probing charm hadronization



- Lund string-based models provides the best description of both EECs?
- HERWIG: overpredicts inclusive jets and underpredicts charm-tagged jets



- SHERPA AHADIC predicts a peak at lower R_L for both EECs → suggests later hadronization compared to other models.

VII. Summary and outlook

1. Charm-tagged vs. inclusive jet EECs:
   - Difference in amplitude → expected from the "dead cone effect"
   - Striking similarity in peak positions → complex interplay: flavor effects in the shower vs. non-perturbative hadronization effects
2. pQCD calculation comparison to charm-tagged jets → needs improved theoretical modeling of heavy quark jets, particularly in the transition region
3. MC model comparisons show sensitivity to different hadronization mechanisms

Many thanks to Kyle Lee and collaborators for providing the pQCD calculations.