Charm jets production and properties with ALICE experiment

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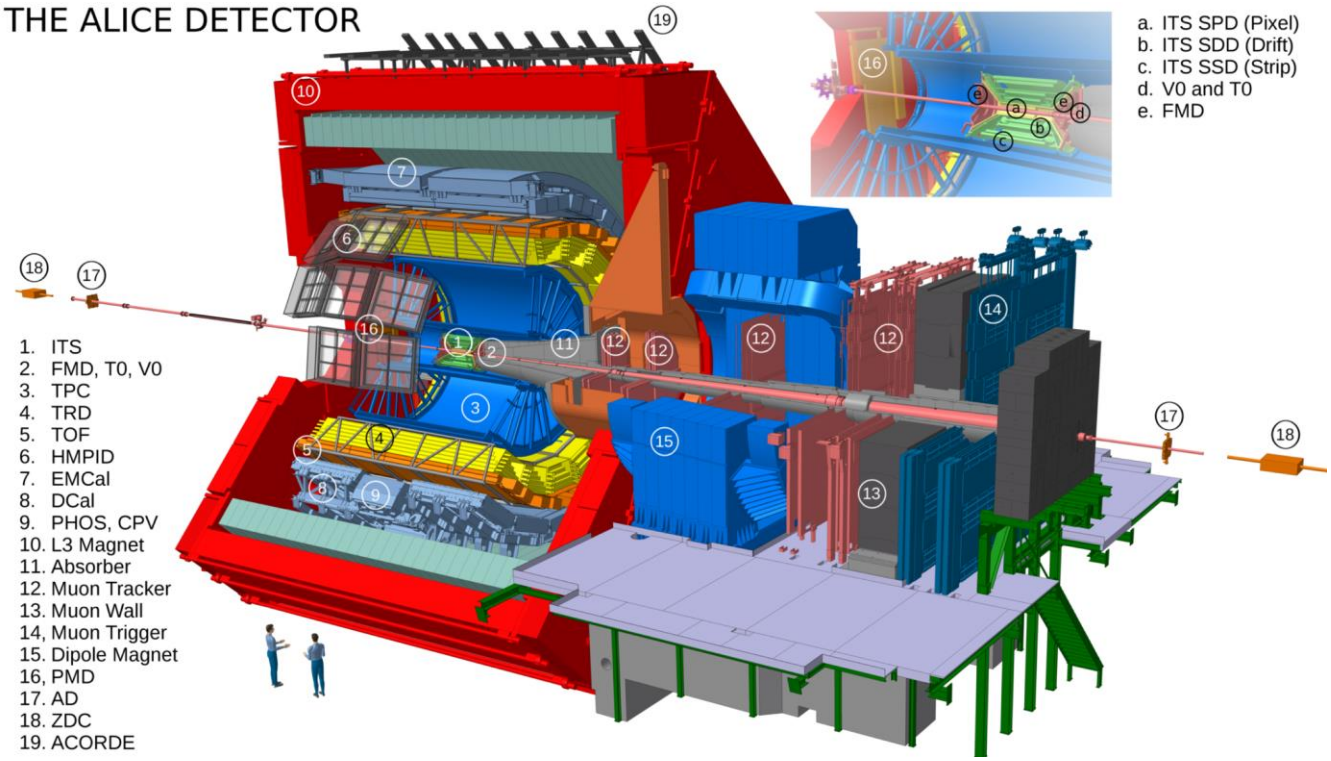
Motivation

- **Heavy flavor hadrons**
  - Heavy quarks (b,c) are mostly produced in hard scatterings at the **initial stage** of the collision
  - measurement down to $\boldsymbol{p_{\mathrm{T}} \approx 0}$
  - Production cross section can be calculated within pQCD
- **HF-tagged jets**
  - Measurement of jets from hard scattering down to very low $p_{\mathrm{T,jet}}$
    - which helps in constraining the **jet background** (even in large systems)
  - Experimental input for gluon-to-hadron Fragmentation Function ($g \rightarrow D^0$) and gluon PDF at low x
  - Quark-enhanced jet sample (w.r.t inclusive jets ⇐ gluon-induced showers)
- **pp**: pQCD test
- **pA**: Cold-Nuclear-Matter effect
- **AA**: Probe of Quark-Gluon Plasma

ALICE Detector

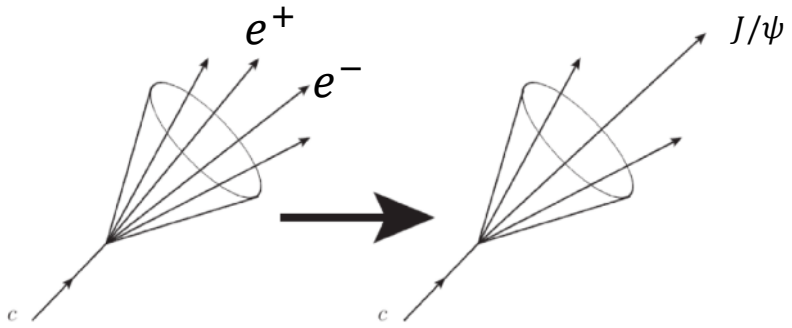


- ITS $|\eta| < 0.9$
  - Vertexing and tracking
- TPC $|\eta| < 0.9$
  - Tracking and PID
- TOF $|\eta| < 0.9$
  - PID
- EMCAL $|\eta| < 0.7$
  - ePID and trigger
- V0 $-3.7 < \eta < -1.7$
  $2.8 < \eta < 5.1$
  - Trigger and background rejection

Analysis Methods

HF-tagged jet reconstruction

- HF hadrons (D, Λ_c, J/ψ) reconstruction with selected channels
- **Replace daughters with hadron candidate**
- Jet clustering with all charged tracks
  - Anti-k_T algorithm, R=0.2/0.4

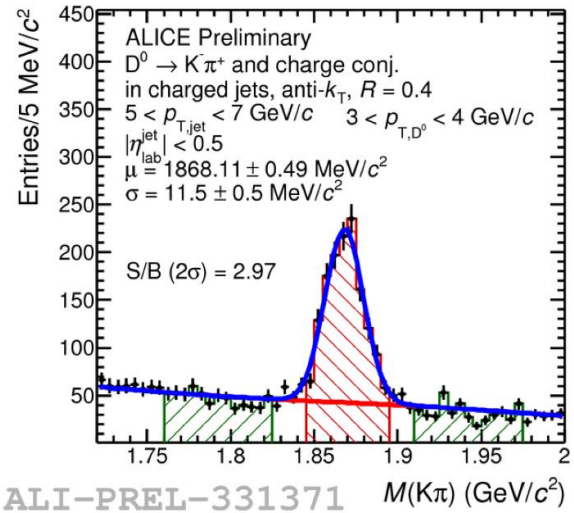


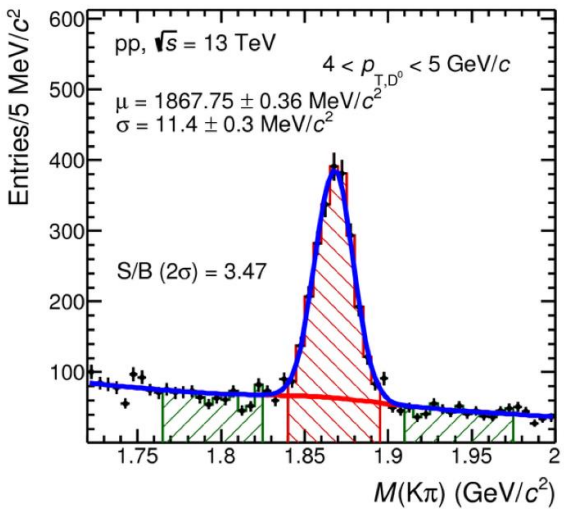
Signal extraction by invariant mass

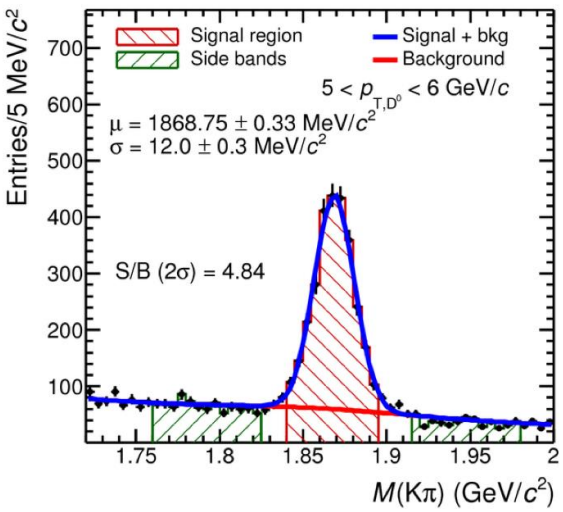
- Fitting raw spectrum
- Side-band method for background subtraction
- Correction on efficiency and beauty feed-down (prompt and non-prompt)
- 2D unfolding $(z, p_{T,jet})$ for detector effect

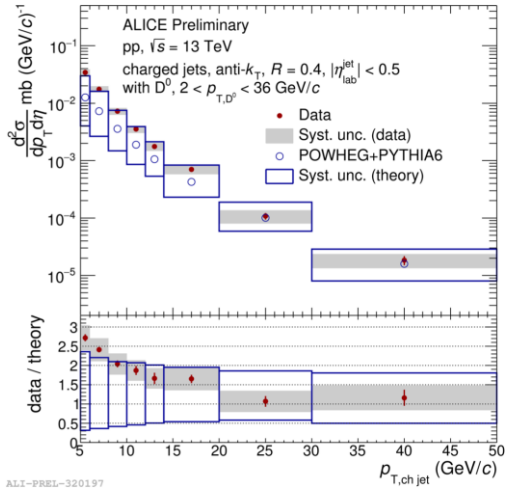
$D^0 \to K^-\pi^+ + conj$ (B.R. 3.89%)
$\Lambda_C^+ \to pK_S^0 + conj.$ (B.R. 1.59%)
$J/\psi \to e^+e^-$ (B.R. 5.97%)

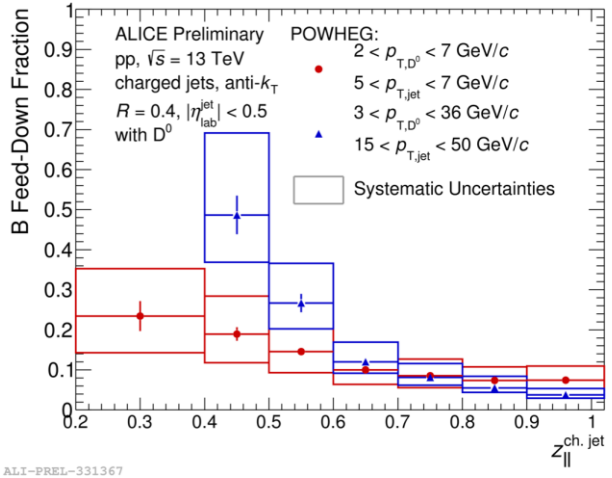
D^0-tagged jet

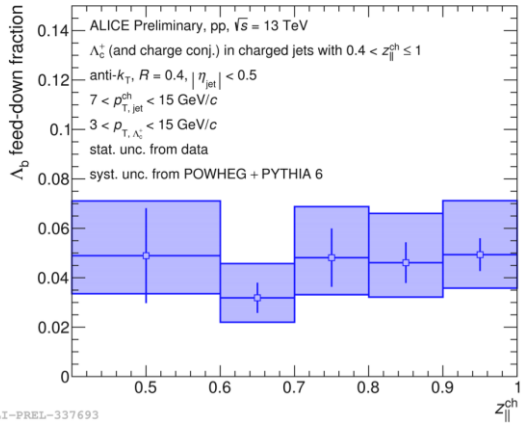






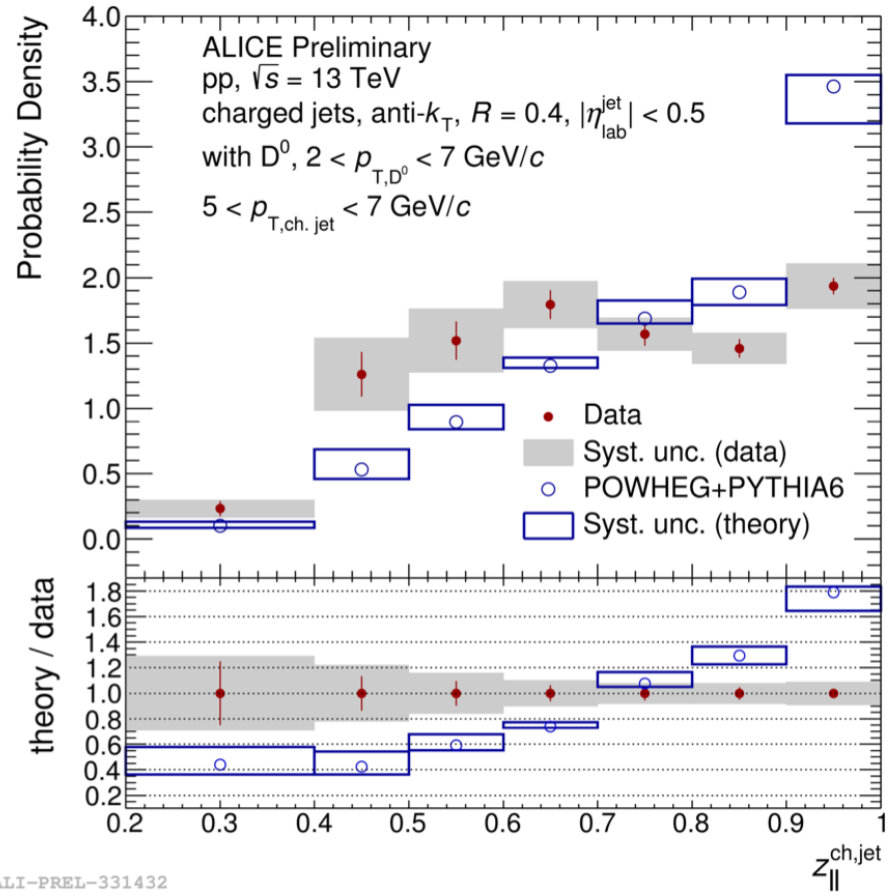


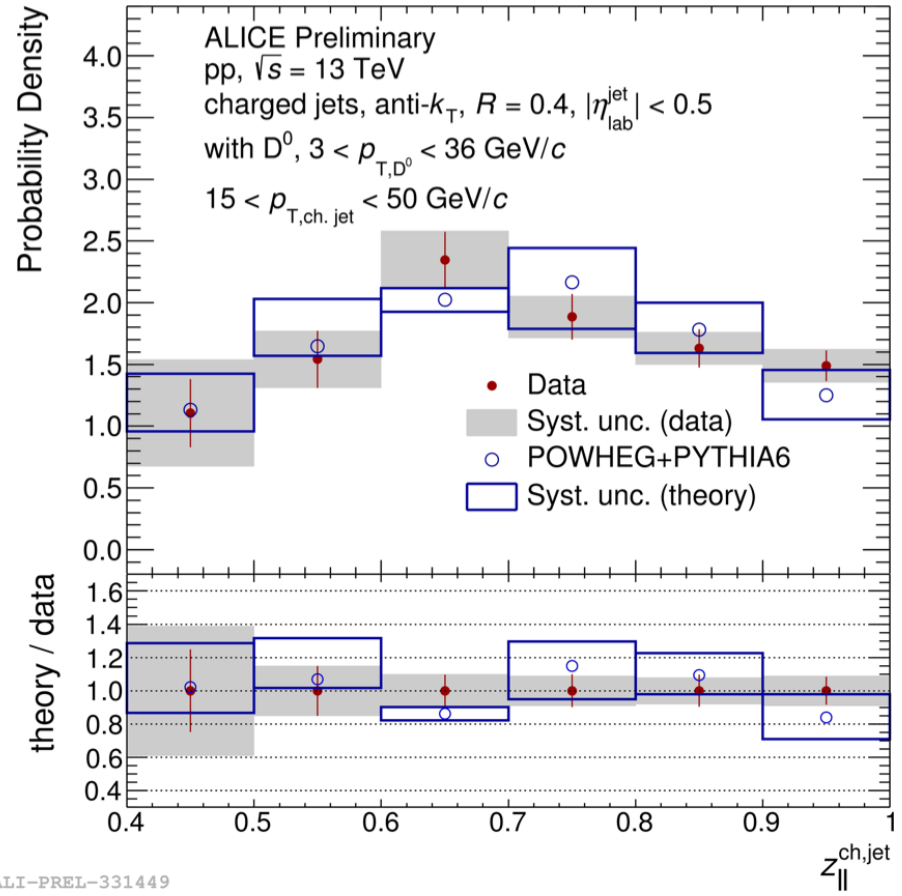




D^0-tagged jet

$z = p_{T,D^0}/p_{T,jet}$

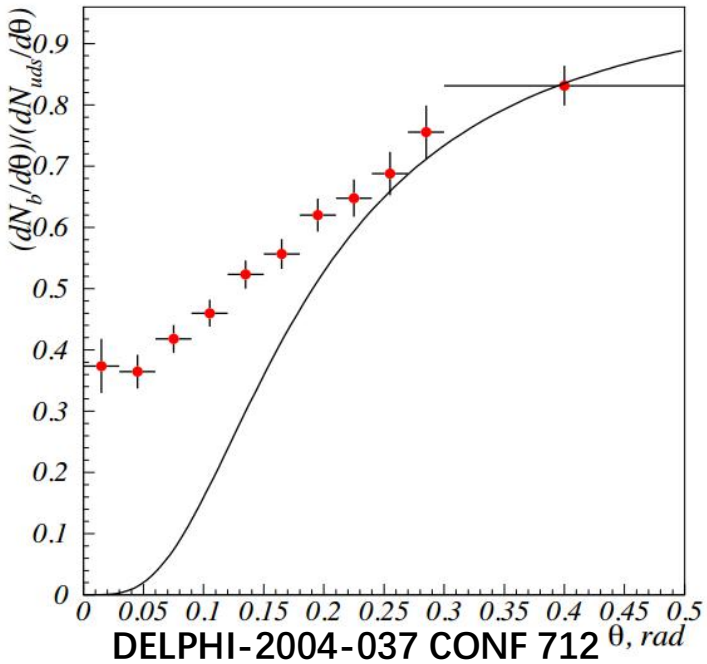




Dead cone effect

- Definition
  - Forward emissions from radiators with large mass are suppressed
  - In QCD this leads to a change in the expected fragmentation of heavy and light quarks
- From LEP

$$\theta = \frac{m_q}{E_q}$$



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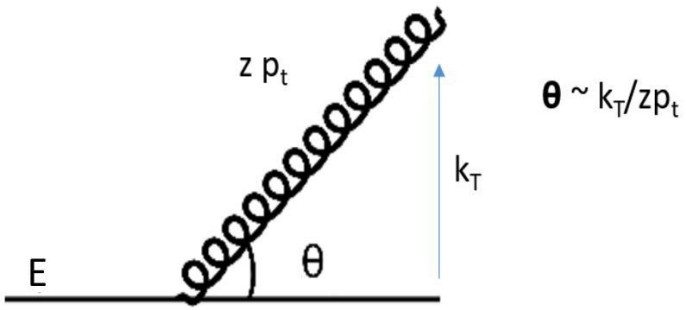
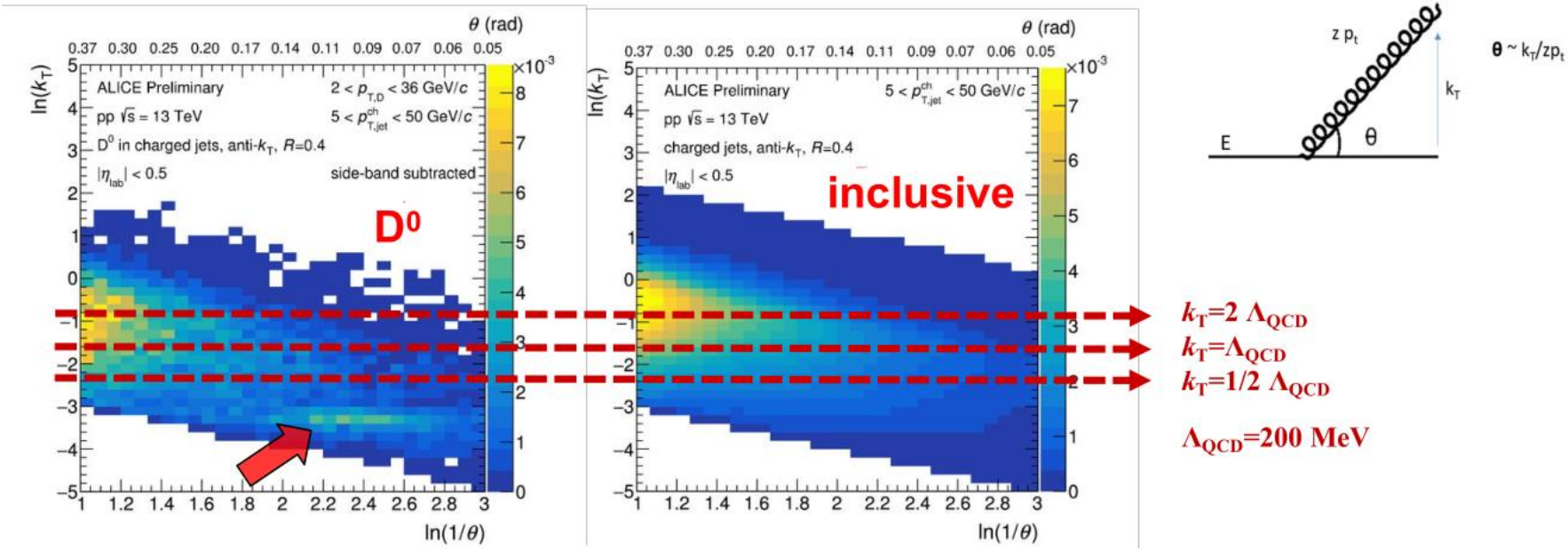


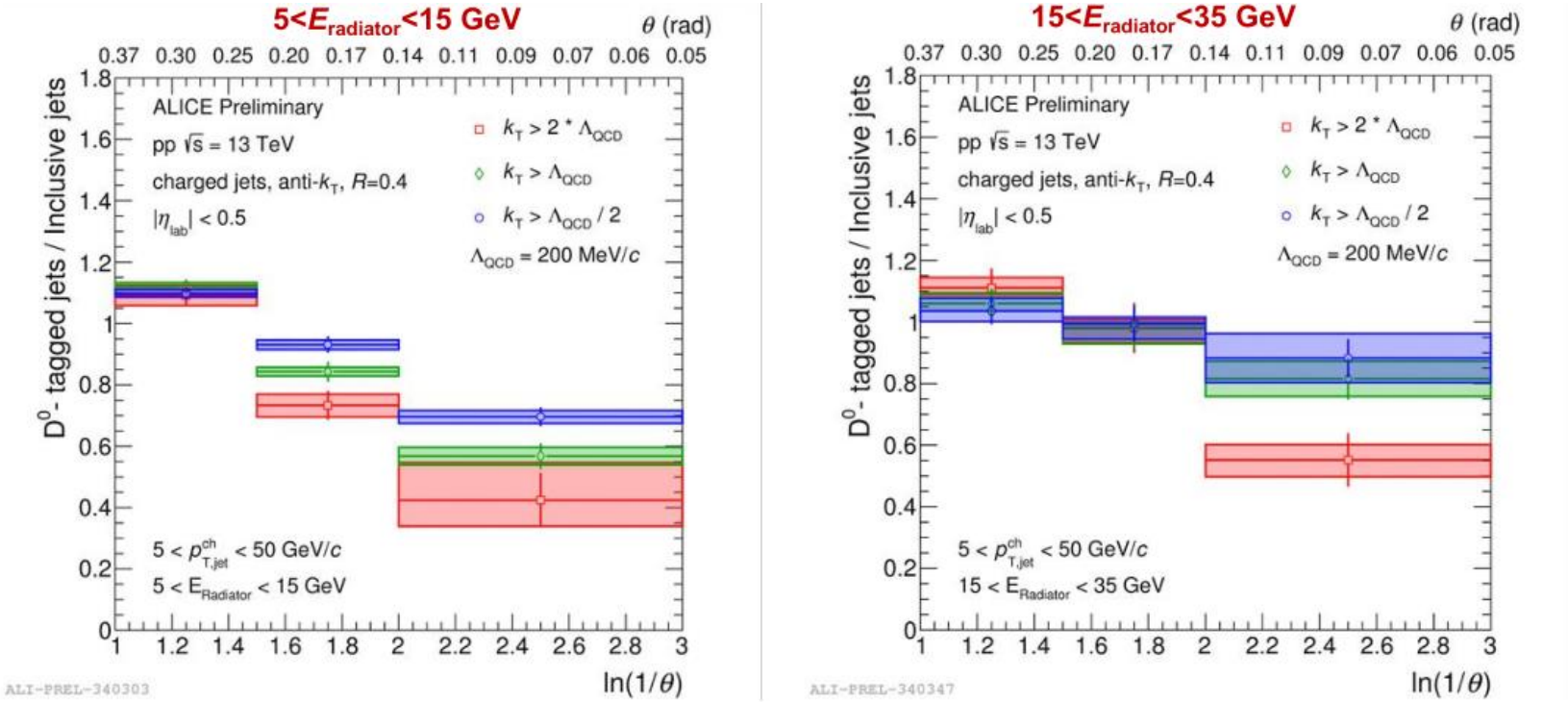
Dead cone effect

- Lund Plane
  - D^0 as well as inclusive jets: Reclustering with C/A
  - Lund plane populated with all splittings of the radiator's prong
- D^0 depletion expected at low angles (~higher ln(1/θ) values)
- Note: 10 to 15% feed-down contribution in D^0 from b



Dead cone effect

- D-tagged to inclusive ratios vs $\ln(1/\theta)$ at pp $\sqrt{s}$=13 TeV

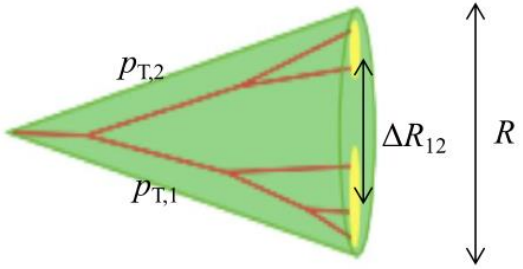


Significant suppression of radiation in D-tagged jets towards low angles
effect decreases toward higher energy of the radiator ($\rightarrow \theta > m_q/E_q$)
effect decreases towards lower kT cut ($\rightarrow$ more contamination)

Groomed substructure

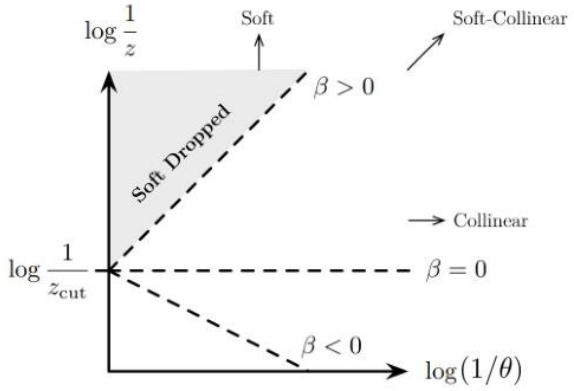
- Access to the hard parton structure of a jet
  - Mitigate influence from underlying event, hadronization
  - Direct interface with QCD calculations
- **Soft-drop grooming**: Remove large-angle soft radiation
  - Recluster a jet with Cambridge-Aachen algorithm (angular ordered)
  - Iteratively remove soft branches not fulfilling

$$z > z_{\text{cut}}\theta^{\beta}$$



$$z = \frac{p_{T,2}}{p_{T,1} + p_{T,2}}$$

$$\theta = \frac{\Delta R_{12}}{R}$$



Larkoski, Marzani, Soyez, Thaler, JHEP 1405 (2014) 146

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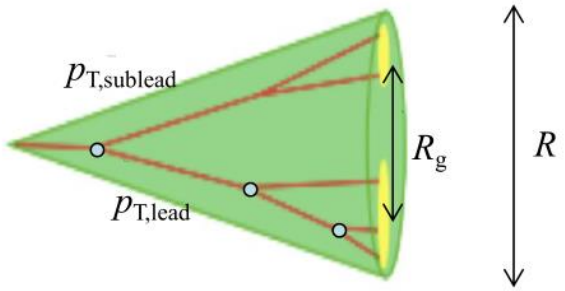


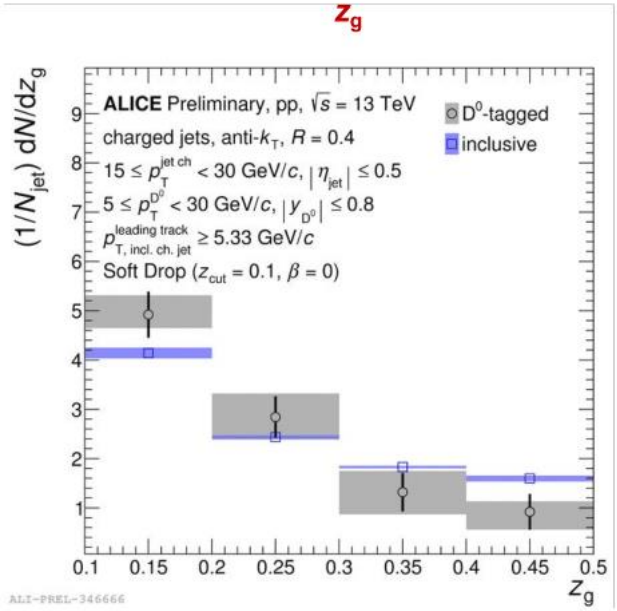
$$z_g = \frac{p_{T,sublead}}{p_{T,lead} + p_{T,sublead}}$$

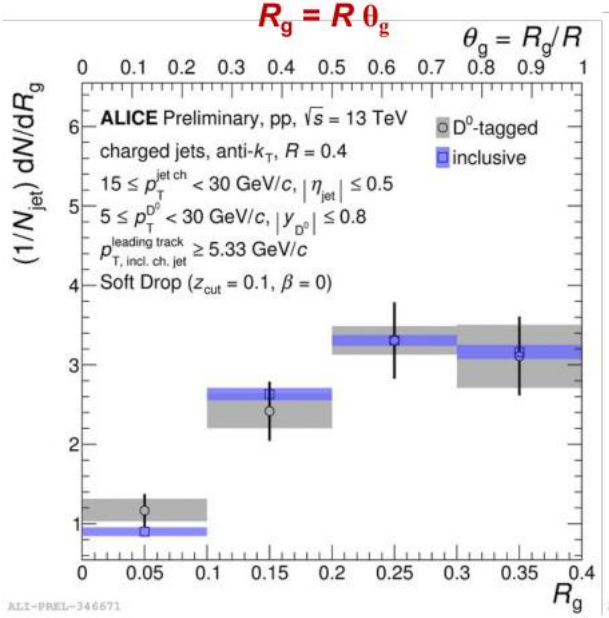
$\theta_g \equiv R_g/R$ - groomed radius

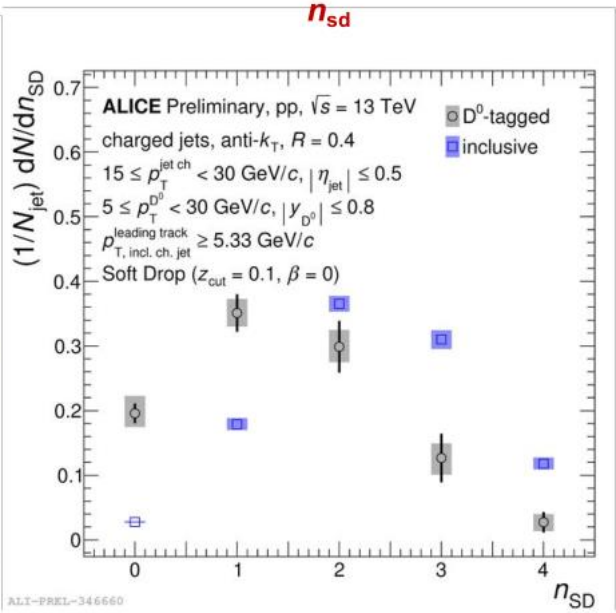
n_{SD} - number of soft drop splittings

Groomed substructure

- Measurement with D^0-tagged jets
  - pp $\sqrt{s}$=13 TeV, z_{cut}=0.1, β=0







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n_{SD}: charm jets typically have less hard splitting than light jets
→ Consistent with harder heavy-flavor fragmentation (mass and color charge effects)

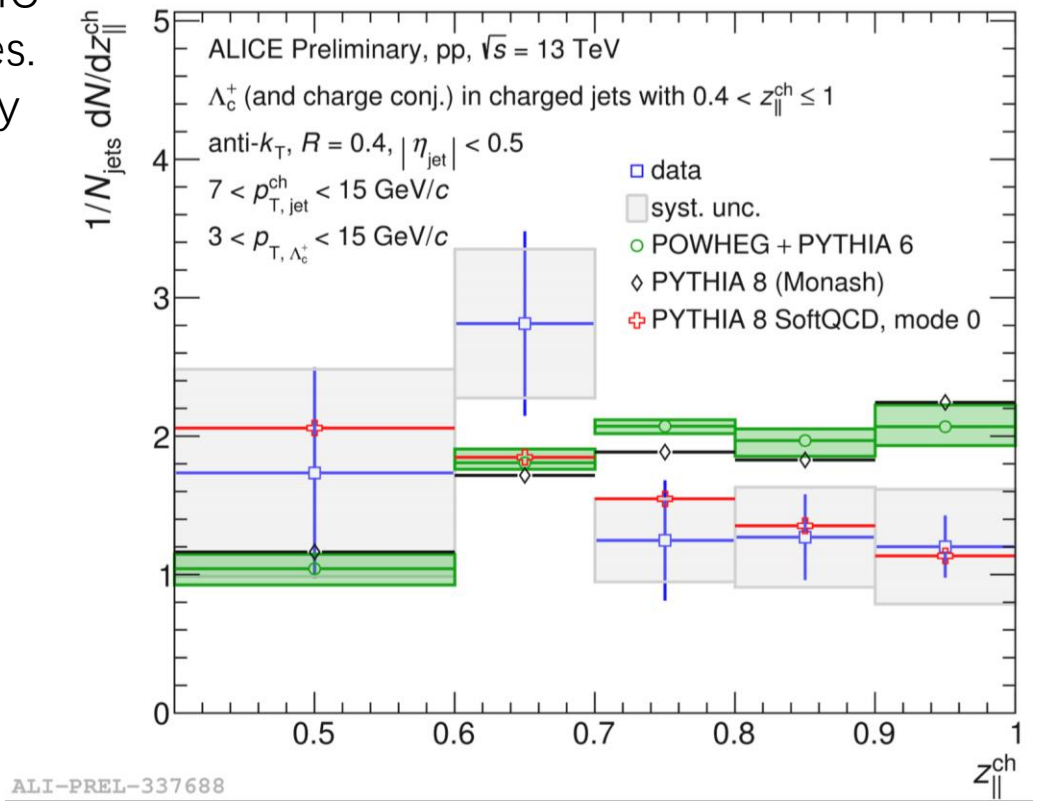
Λ_c^+-tagged jet

$$z = p_{T,\Lambda_c^+} / p_{T,jet}$$

- First measurement of Λ_c^+ in jets at LHC
- Measurement with large uncertainties.
- Exciting prospects for high luminosity LHC run!

Comparison to model

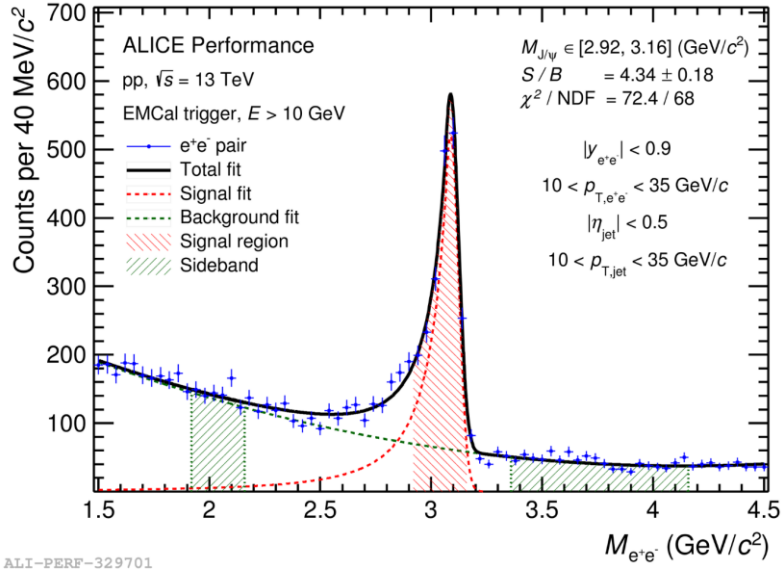
- POWHEG hvq CT10NLO + PYTHIA6
- Softer fragmentation in data
- Seems to favor PYTHIA with softer settings
- Allow to put constrains on models

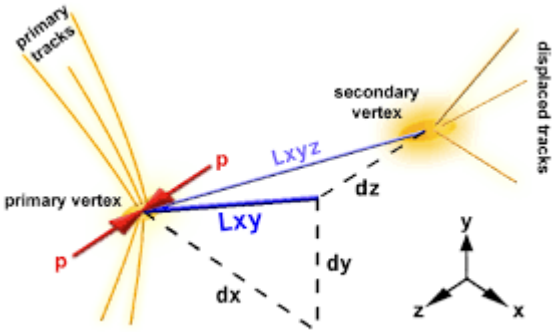


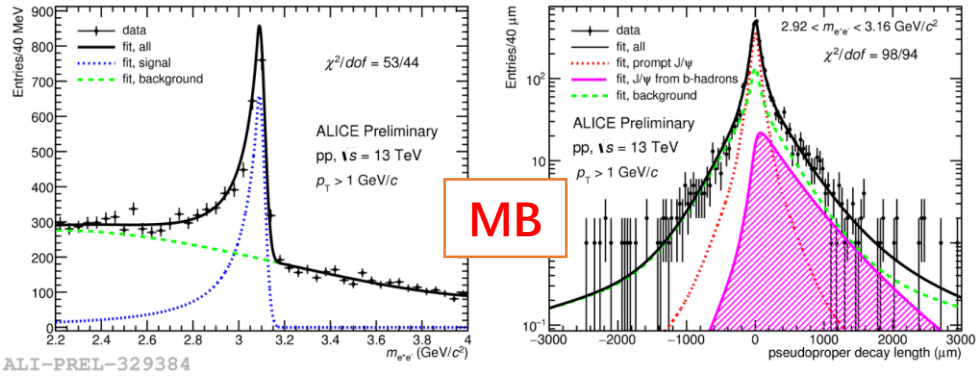
J/ψ-tagged jet

- For J/ψ analysis, using EMCal triggered events
- Separate prompt and non-prompt components by cuts on pseudo-proper decay length

$$\tilde{L}_{xy} = L_{xyz} \times \frac{cm_{J/\psi}}{|p_{e^+e^-}|}$$

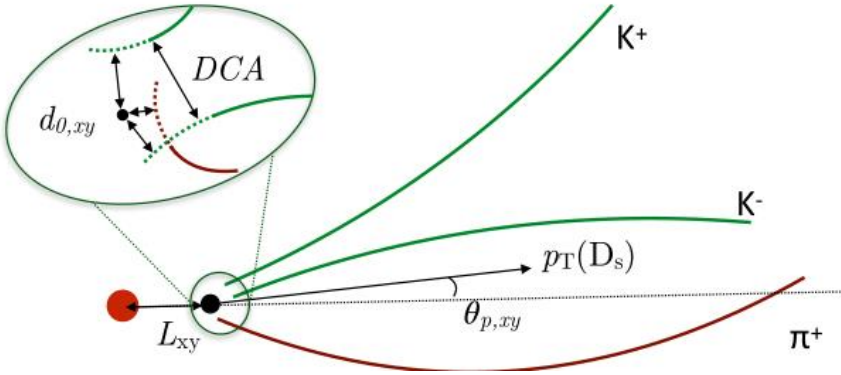


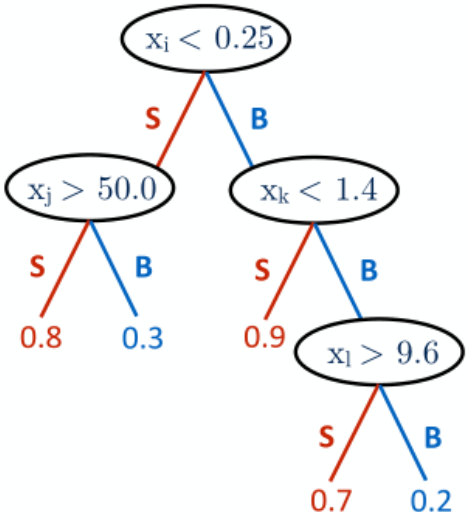


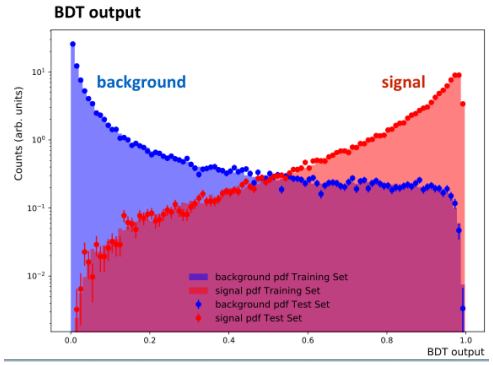


D_s analysis

- $D_s \rightarrow \phi(1020)\pi \rightarrow K^+K^-\pi$
- Topological reconstruction
  - triplet of charged tracks: (+,-,+) or (-,+,-) coming from a reconstructed decay vertex
  - signal + combinatorial background
- BDT method
  - Input features: topological and kinematic variables + PID info.







Summary

- D-tagged jets
  - p_T differential cross-section consistent with theory
  - D-meson jet momentum fraction in pp shows softer fragmentation in data for low $p_{T,jet}$
  - test dead-cone effect directly
  - compare groomed jet substructure
- Λ_c-tagged jets
  - First measurement at LHC
  - Allow to put constrains on models

- Outlook
  - Analysis in heavy ion collision (Pb-Pb data)
  - J/ψ-tagged jets at low-pT region
  - D_s in jets at pp 13 TeV