EMMI Physics Day 2019

Investigating the properties of heavy-flavour jets with ALICE

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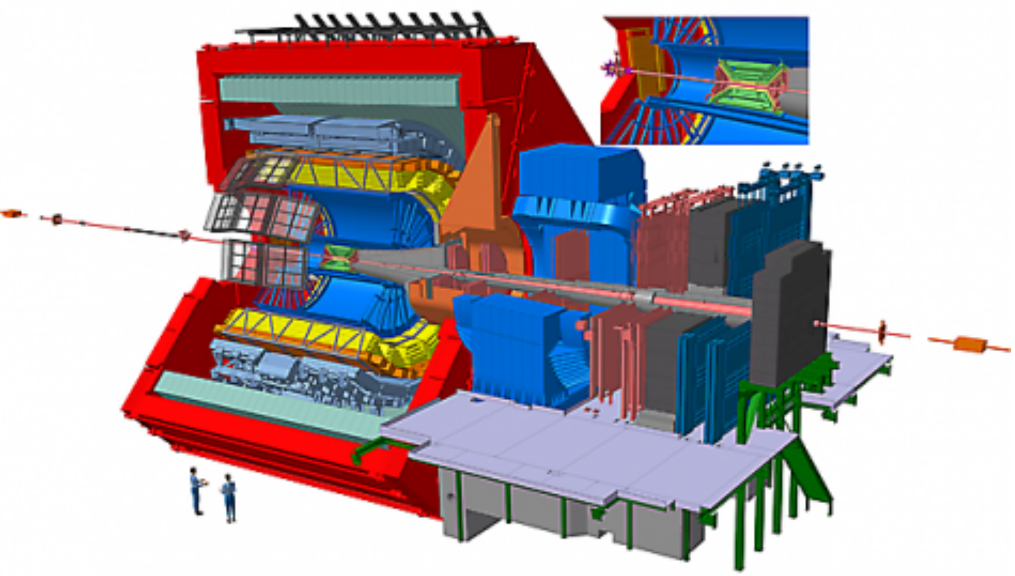
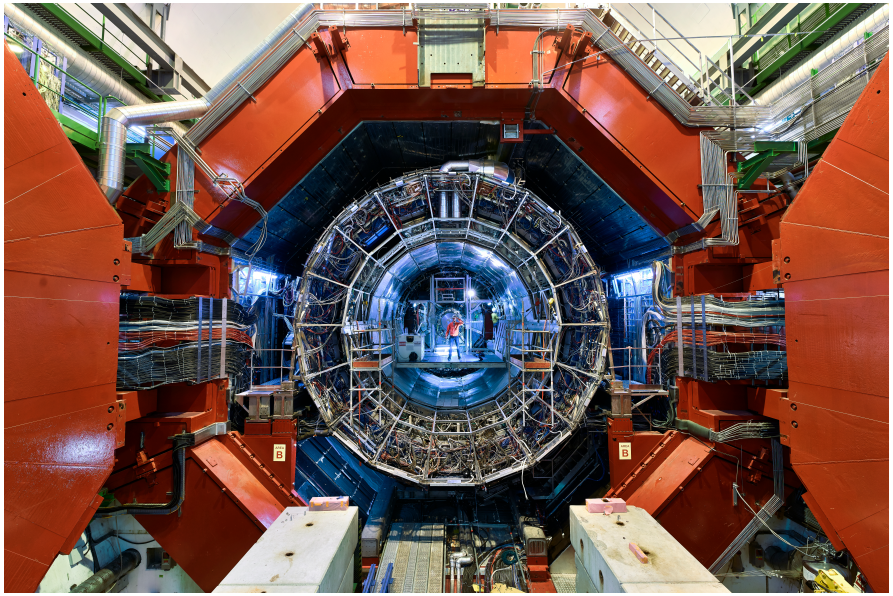
WWU MÜNSTER

ALICE @ LHC

- ALICE is designed for heavy-ion collisions at the CERN Large Hadron Collisions (LHC)

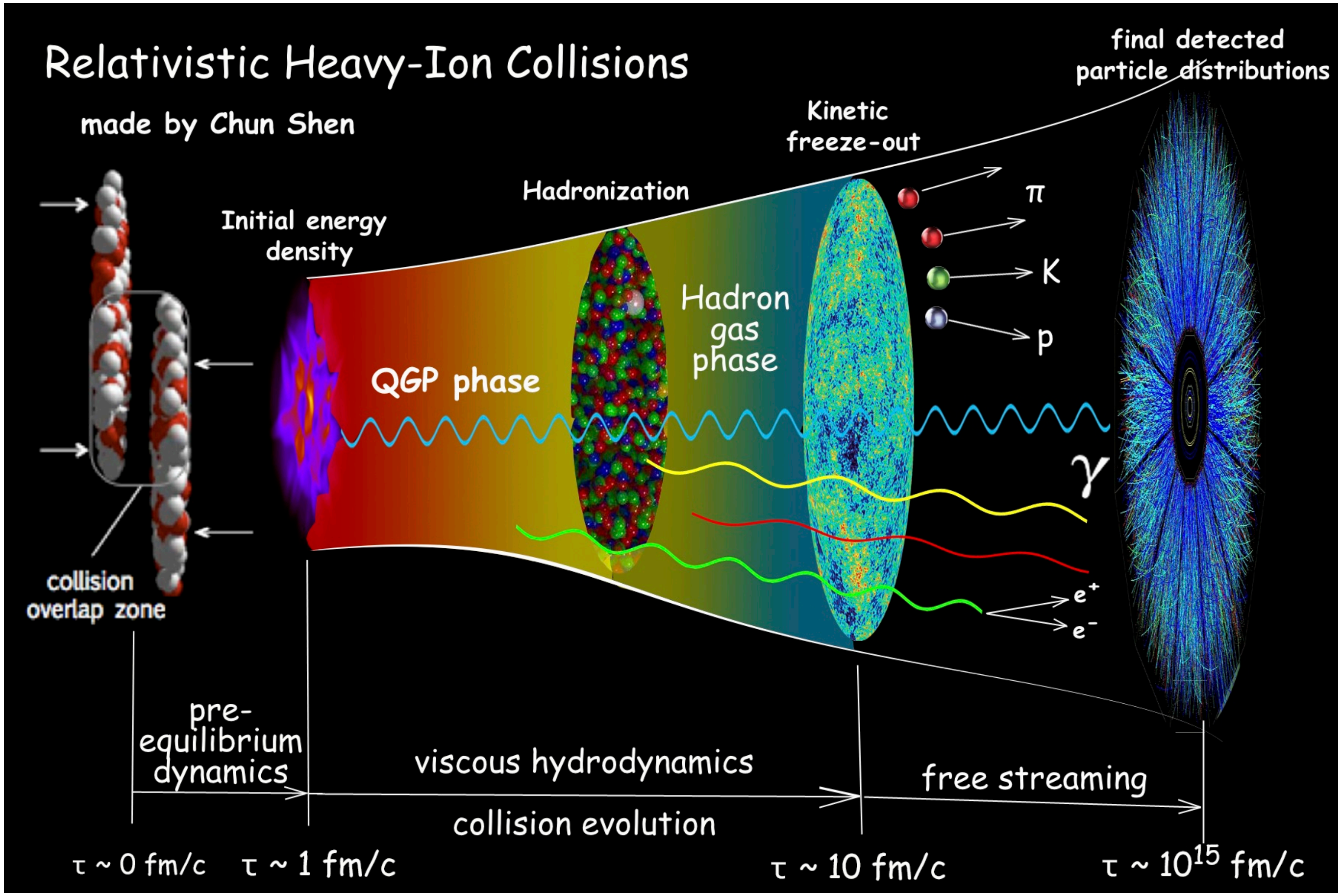
System	$\sqrt{s_{NN}}$ (TeV)
pp	0.9, 2.76, 5.02, 7, 8, 13
p-Pb	5.02, 8.16
Pb-Pb	2.76, 5.02
Xe-Xe	5.44





ALICE, March/2019

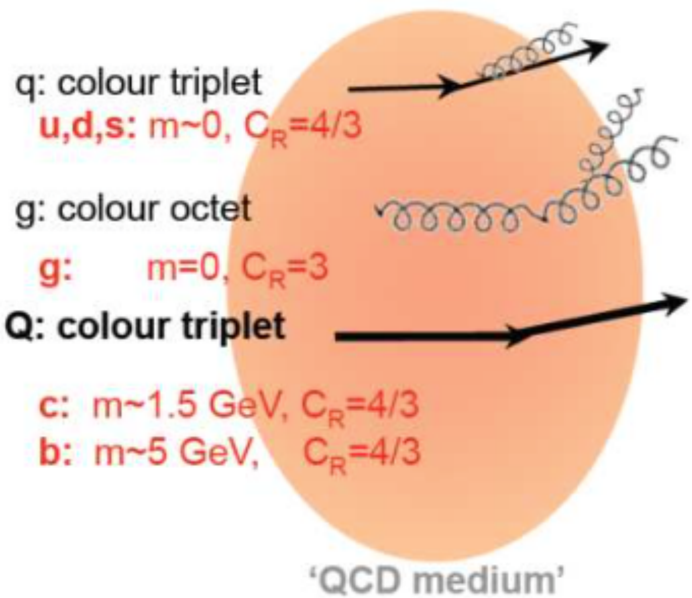
Physics of heavy-ion collisions



- **Quark-Gluon Plasma (QGP):** deconfined state of quarks and gluons created in heavy-ion collisions at high energy and in the early Universe (until about 10μs)

What are heavy flavours?

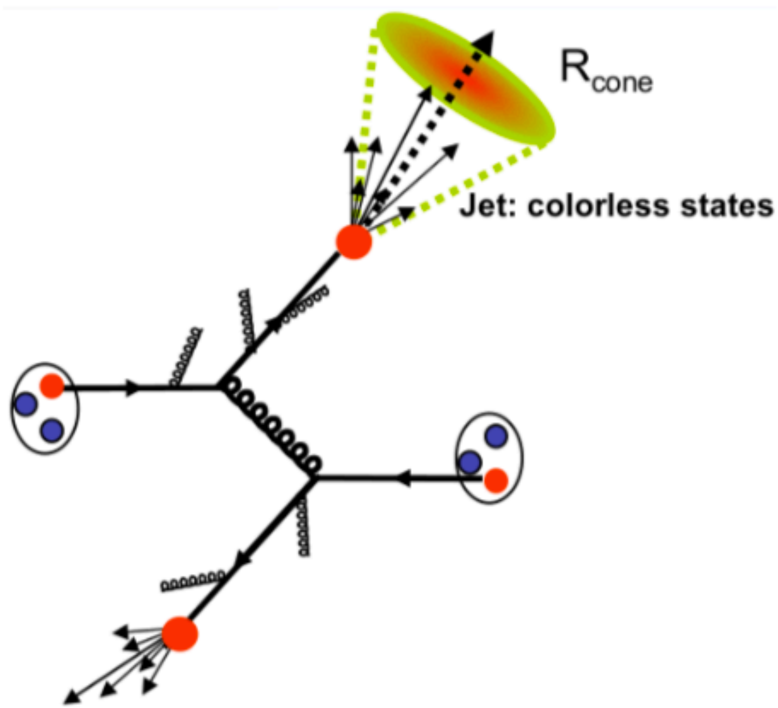
- Heavy flavours (charm and beauty) are produced predominantly in the early stages of collisions because of their large masses
  - ➢ $m_c \approx 1$ GeV and $m_b \approx 4$ GeV
- Formation time: $t_Q \approx 1/2m_Q$
  - ➢ $t_c \approx 0.1$ fm/c and $t_b \approx 0.02$ fm/c
- Open heavy flavours: e.g. $D^0 = c\bar{u}$



Medium effects:

- Collisional and radiative energy loss processes
- Dependence on:
  - ➢ Medium density and volume
  - ➢ Colour charge (Casimir factor): **ΔE(gluon) > ΔE (quark)**
  - ➢ Quark mass (dead cone effect): **ΔE(light quark) > ΔE(charm) > ΔE(beauty)**

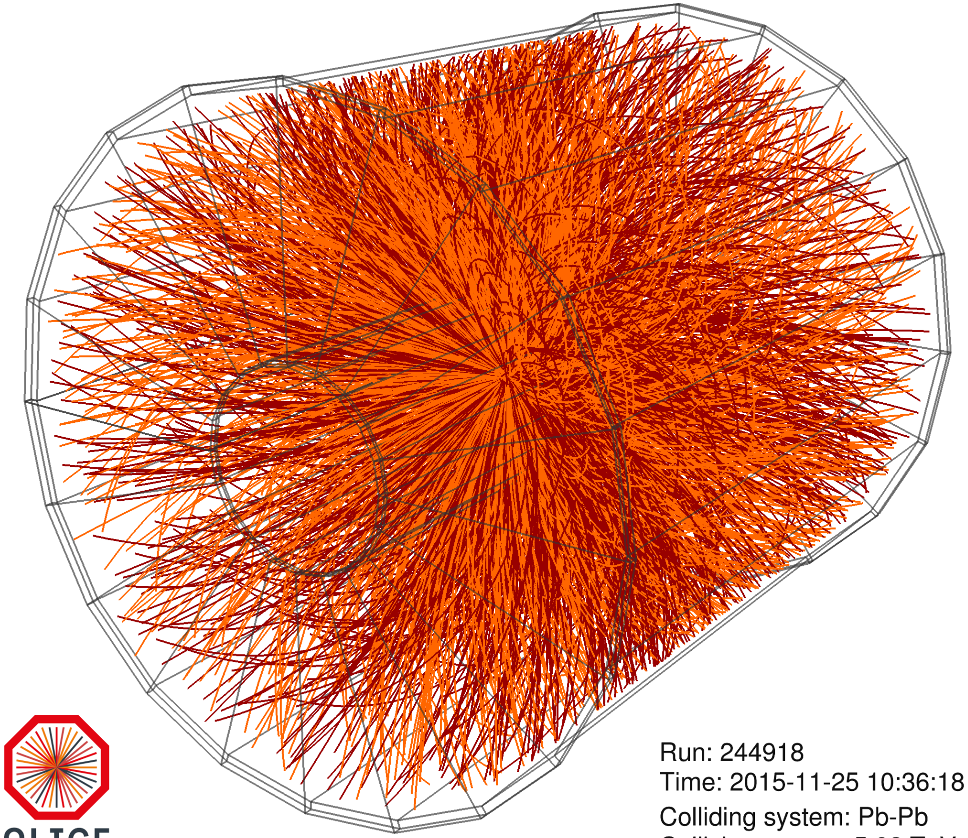
What is a jet?



- A jet consists of final state hadrons that fragmented from a hard scattered parton (quark or gluon)
- Jets are a proxy for the initial scattered partons

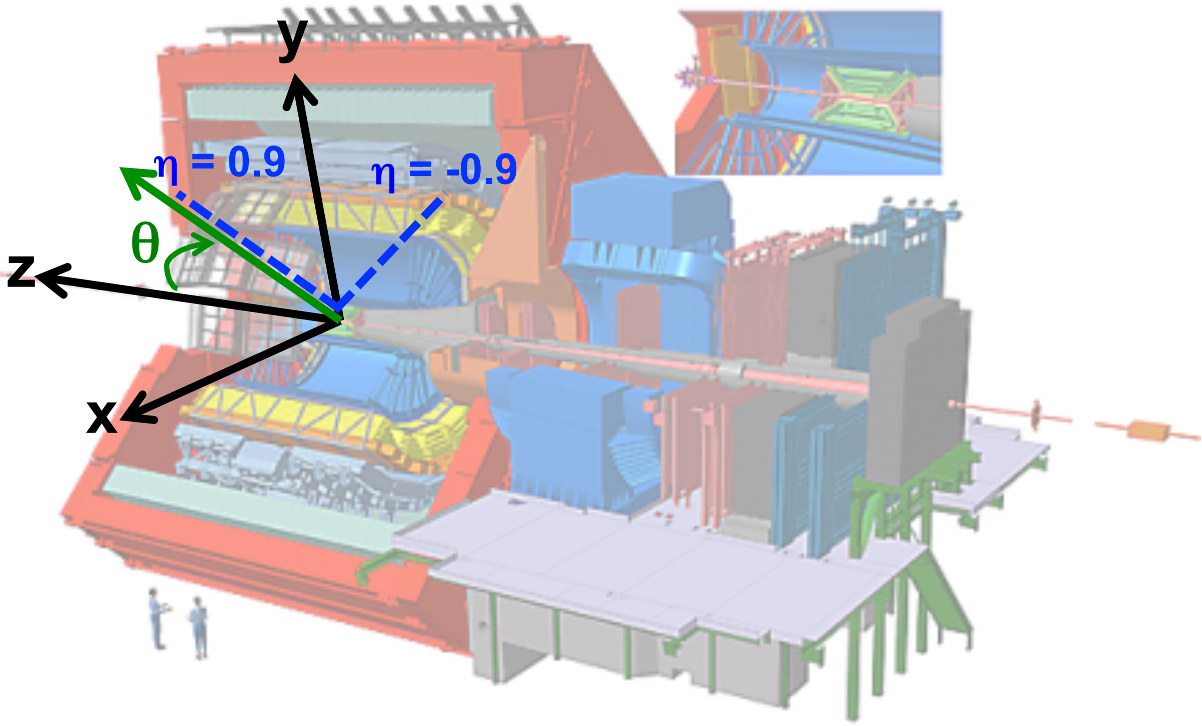
Medium effects:
- Jet energy loss
- Modification of the jet shape and the fragmentation function

How do we measure heavy-flavour jets in ALICE?



Run: 244918
Time: 2015-11-25 10:36:18
Colliding system: Pb-Pb
Collision energy: 5.02 TeV

Kinematic variables



Transverse momentum

$$p_T = p \sin\theta$$

Rapidity

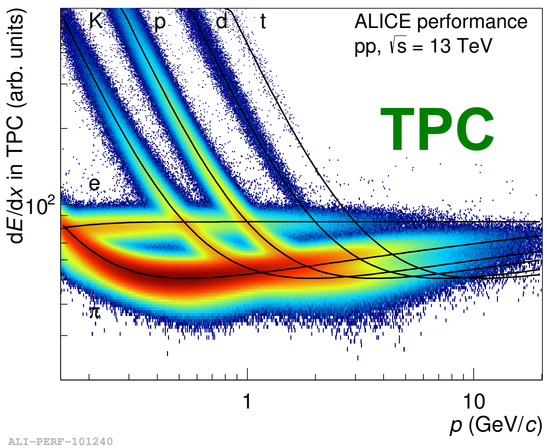
$$y = \frac{1}{2} \ln \frac{E + p_z}{E - p_z}$$

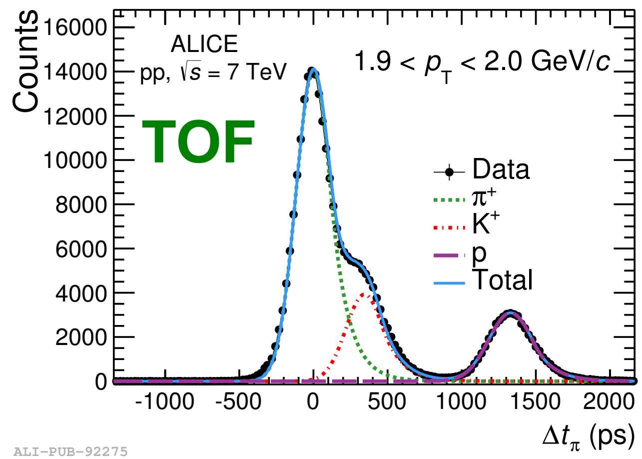
Pseudorapidity

$$\eta = -\ln\left(\tan\frac{\theta}{2}\right)$$

Data analysis

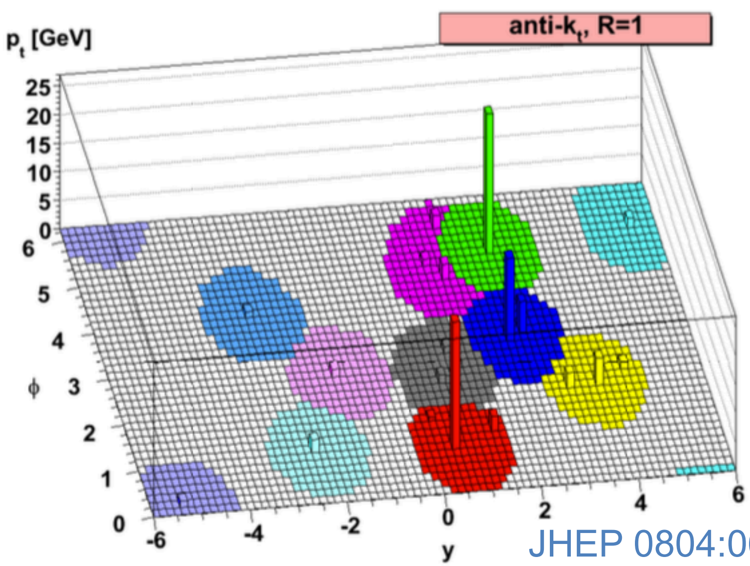
Particle identification





- Based on the particle specific signal in the ALICE subdetectors

Jet reconstruction



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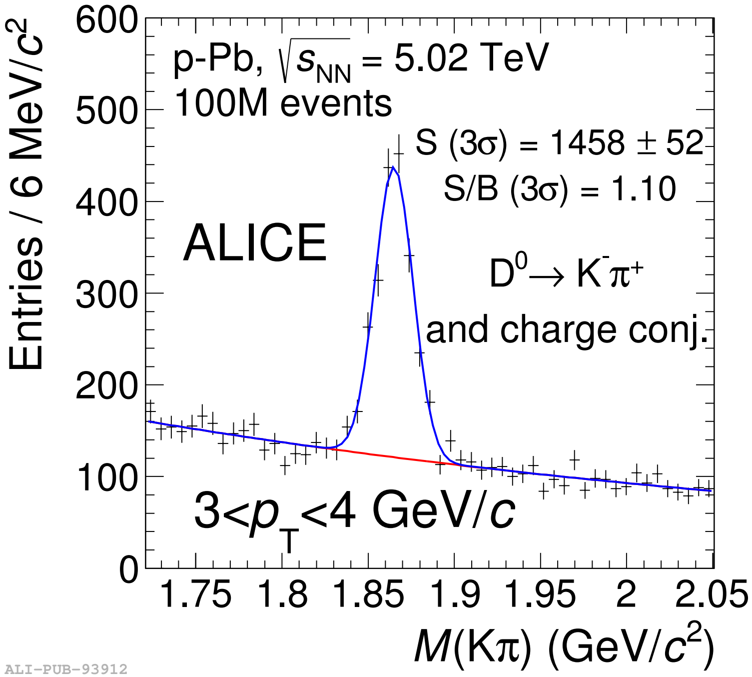
- In ALICE, jets are normally reconstructed with the anti-k_T algorithm
  - ➢ Particles are clustered into jets starting from high-p_T particles
  - ➢ Jets are circular with a radius R
- In the experiment:
  - Full jet reconstruction
  - Charged jet reconstruction

D^0-tagged jet reconstruction

$D^0 \rightarrow K^-\pi^+$ (BR ≈ 3.93%, c_τ ≈ 123 μm)

D^0 meson:
- Identification of π and K
- Reconstruction of decay vertex topologies displaced from the primary vertex
- Signal extracted from the invariant mass distribution

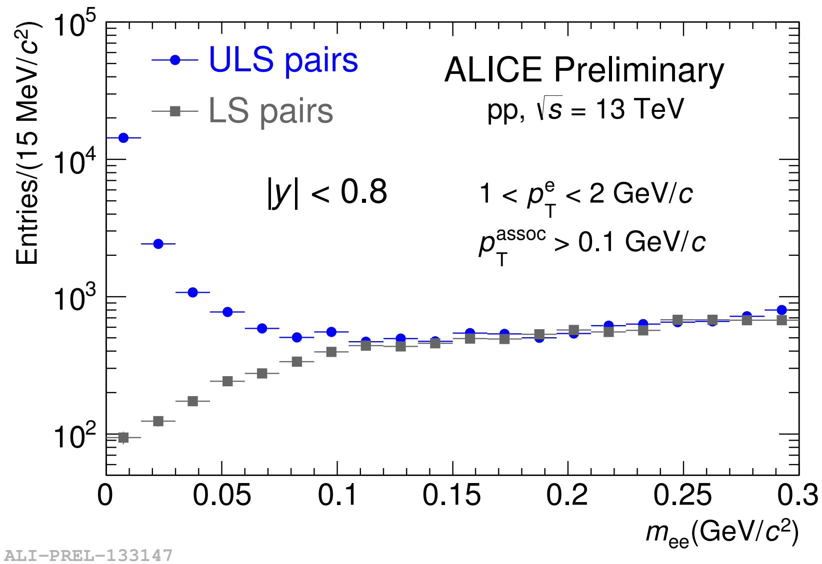


Jet finding:
- Track based
- D^0 meson candidates replace the decay products in the jet finding

HFE jet reconstruction

Electrons from heavy-flavour hadron decays (HFE):

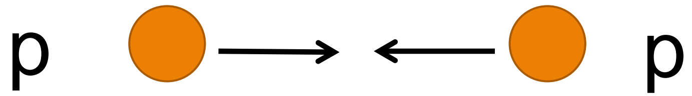
- Identification of electrons
- Subtraction of background hadrons
- Subtraction of non-HFE (mainly electrons from photon conversions and Dalitz decays of light neutral mesons) using invariant mass



Jet finding:

- Track based
- HFE search after the reconstructed jet

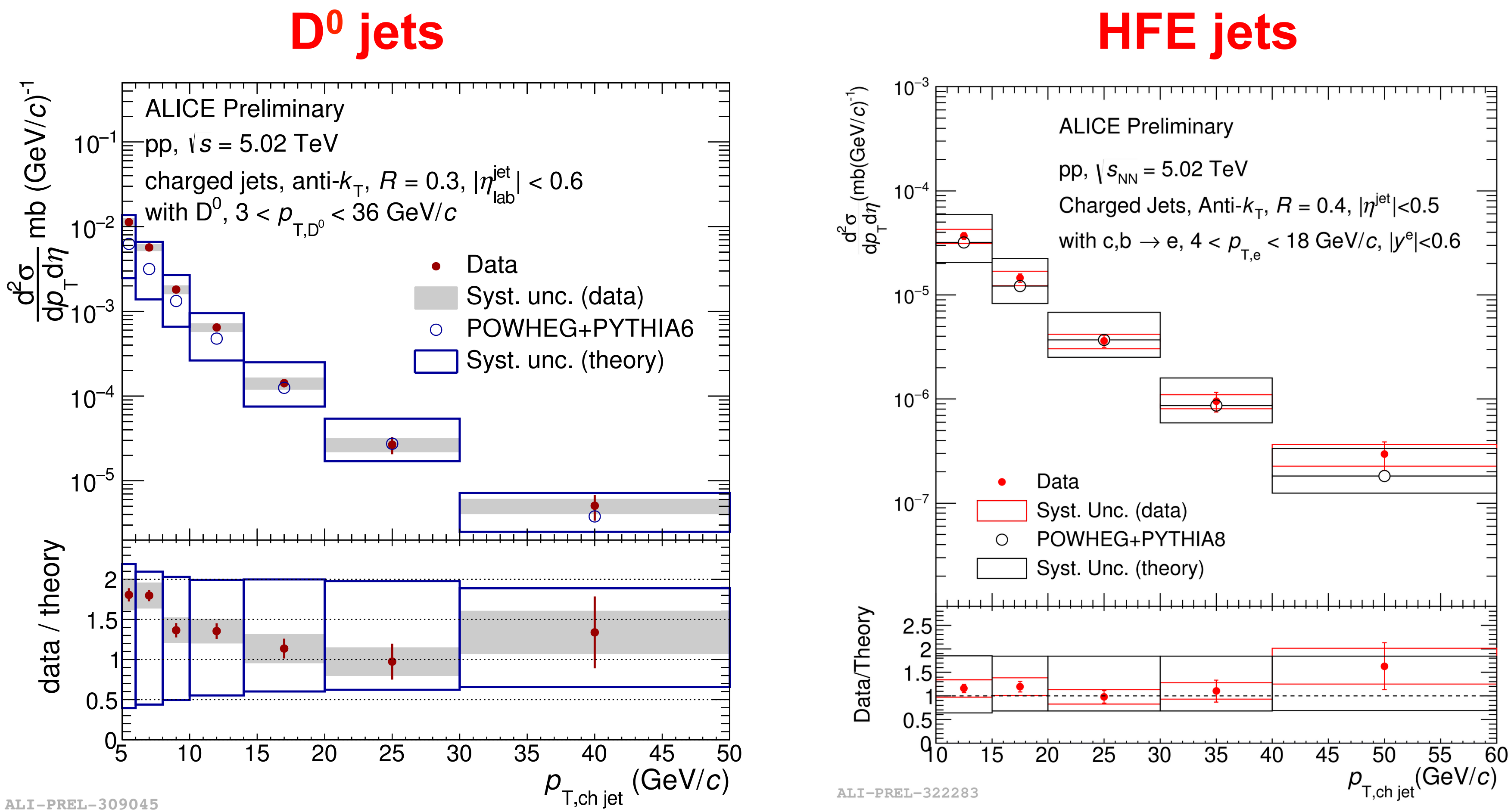
What have we learnt in pp collisions?



Physics motivations:

- Test of perturbative QCD
- Investigate the heavy-flavour fragmentation
- Reference for Pb-Pb and p-Pb collisions

p_T differential cross sections

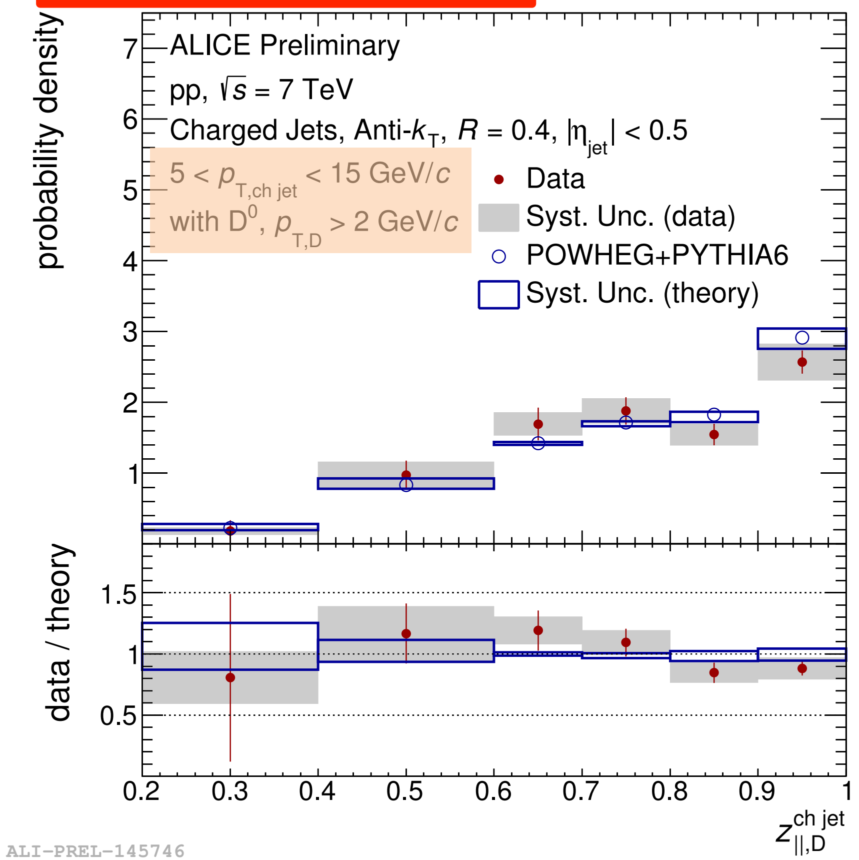


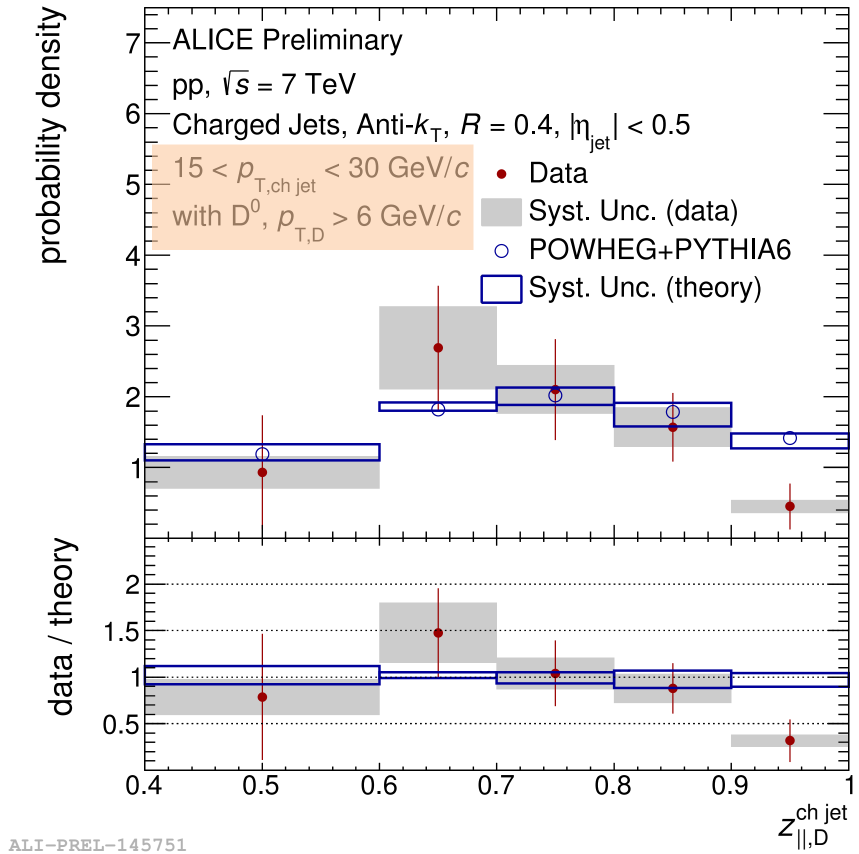
- Agreement with NLO pQCD POWHEG+PYTHIA simulation

D^0-tagged jets: fragmentation

$$z_{||} = \frac{\vec{p}_{\mathrm{ch\ jet}} \cdot \vec{p}_{\mathrm{D}}}{\vec{p}_{\mathrm{ch\ jet}} \cdot \vec{p}_{\mathrm{ch\ jet}}}$$

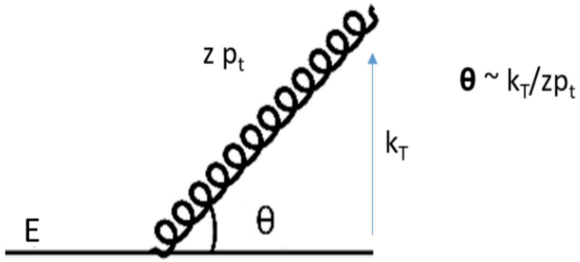
charged jet momentum fraction carried by D^0 mesons in the direction of the jet axis



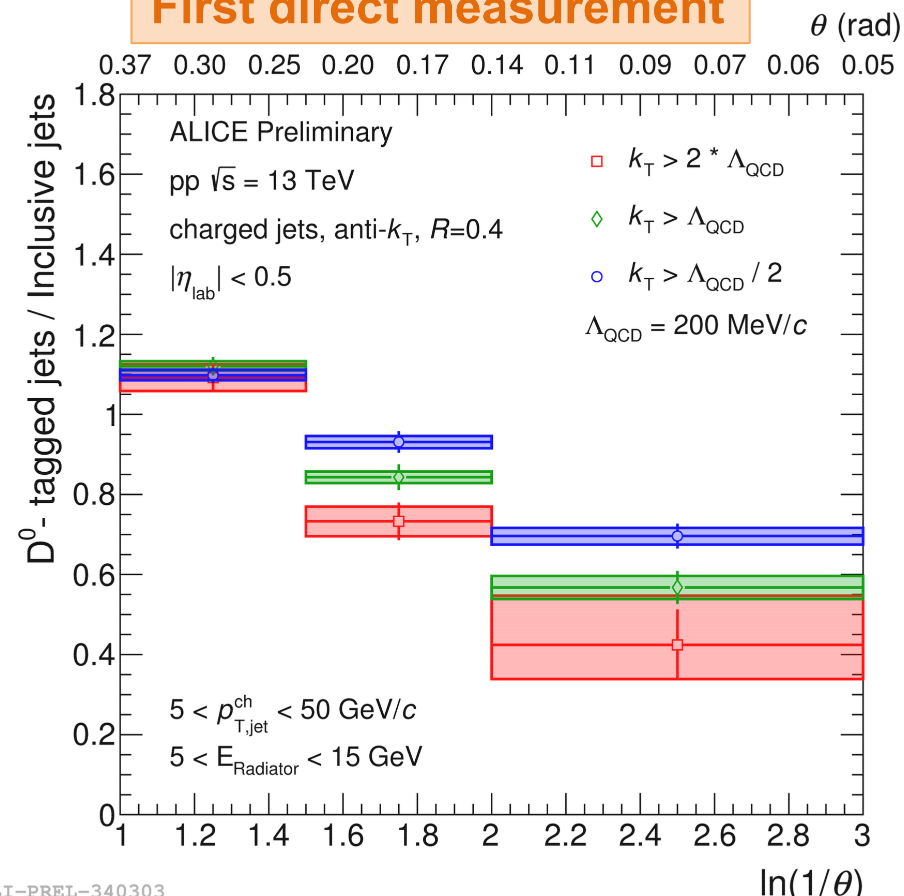


- Agreement with NLO pQCD POWHEG+PYTHIA6 simulation
- Hint of a softer fragmentation for $15 < p_{T,ch}$ jet < 30 GeV/c

D^0-tagged jets: dead cone effect



First direct measurement

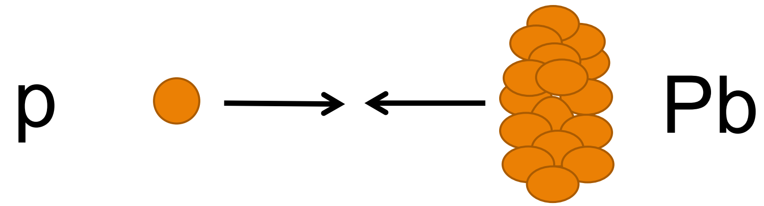


- Gluon radiation from a radiator (quark) is predicted to be suppressed within:

$$\theta < \frac{M_q}{E_q}$$

- Suppression of splittings at small angles in heavy flavour jets due to the dead-cone effect
- The magnitude of suppression increases at smaller angles and with stricter cuts on k_T

What have we learnt in p-Pb collisions?

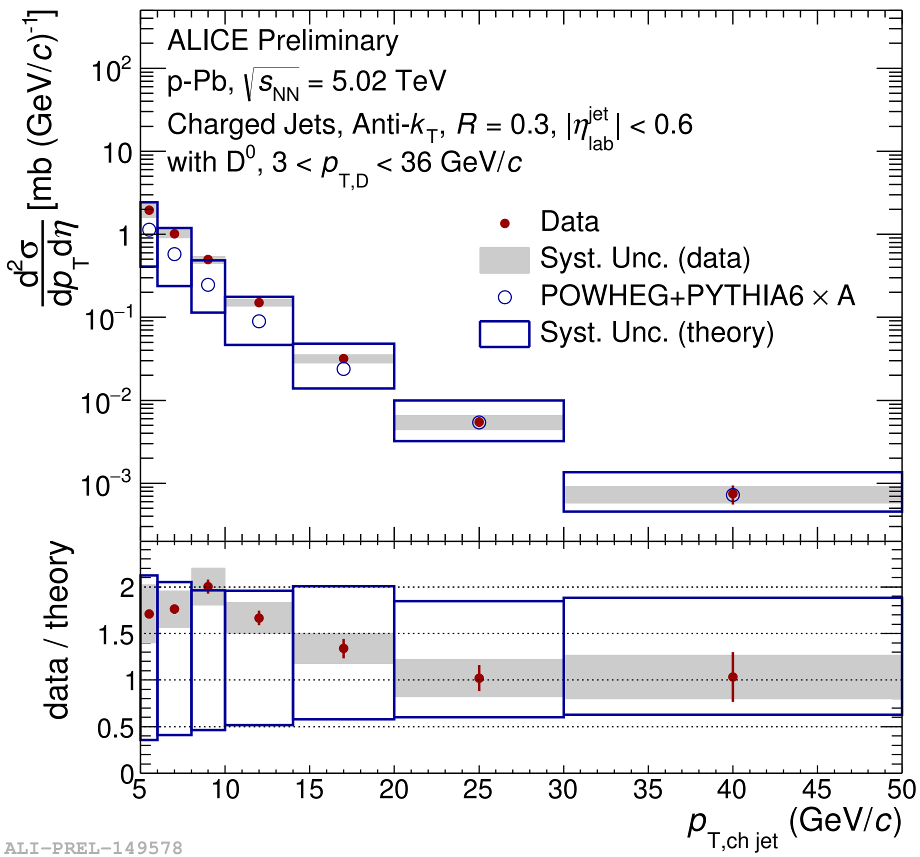


Physics motivation:

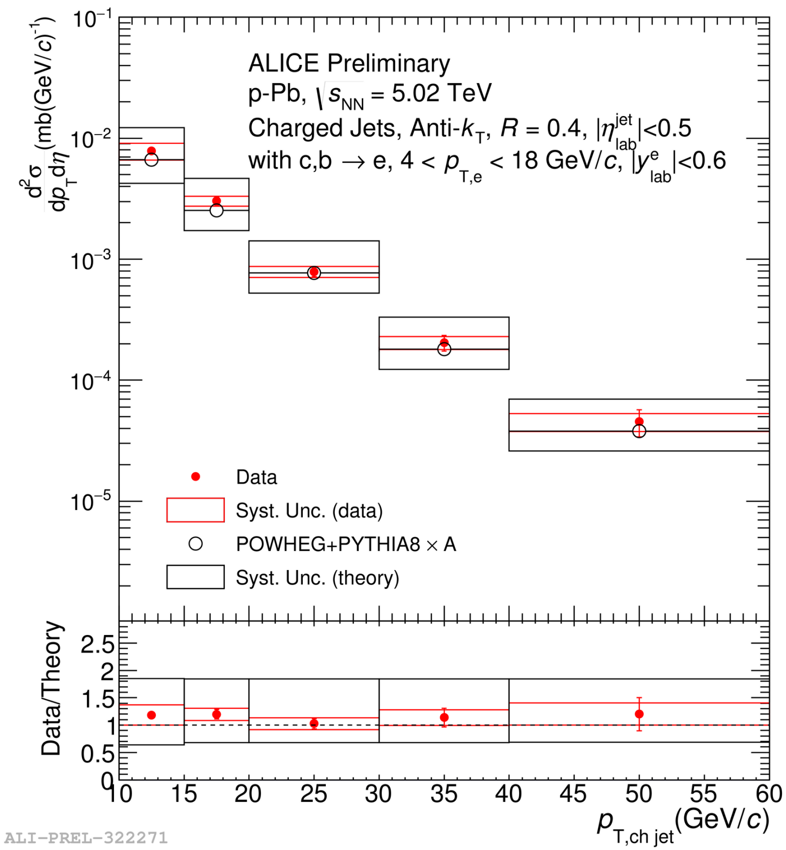
- Investigate cold nuclear matter (CNM) effects

p_T differential cross sections

D⁰ jets



HFE jets

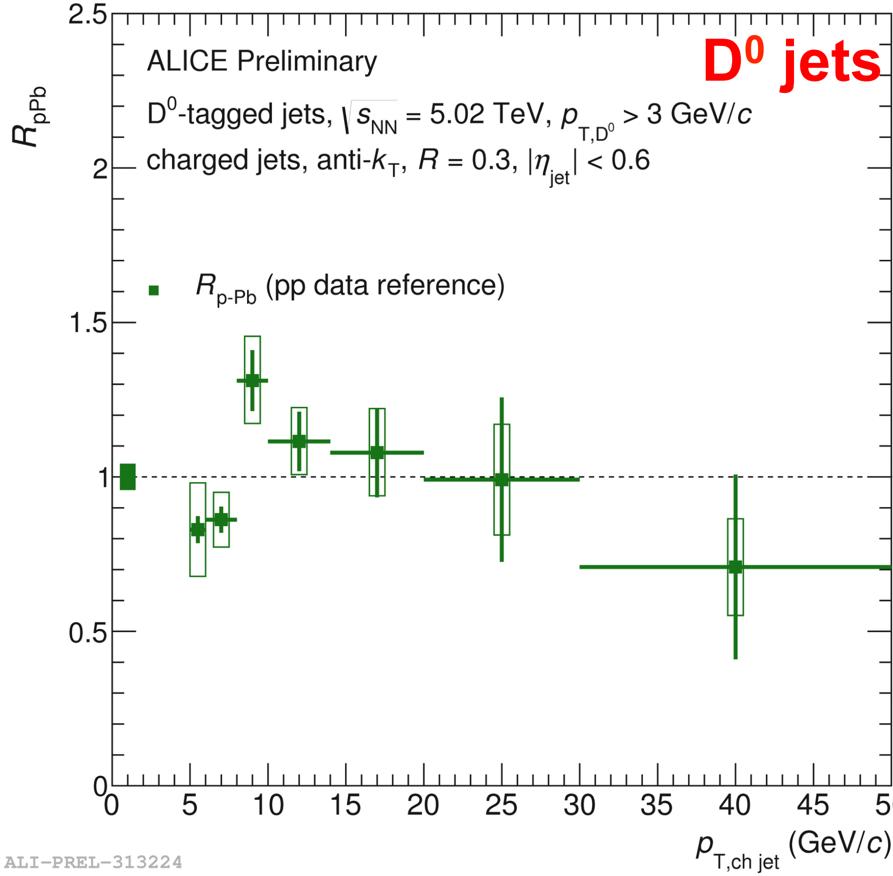


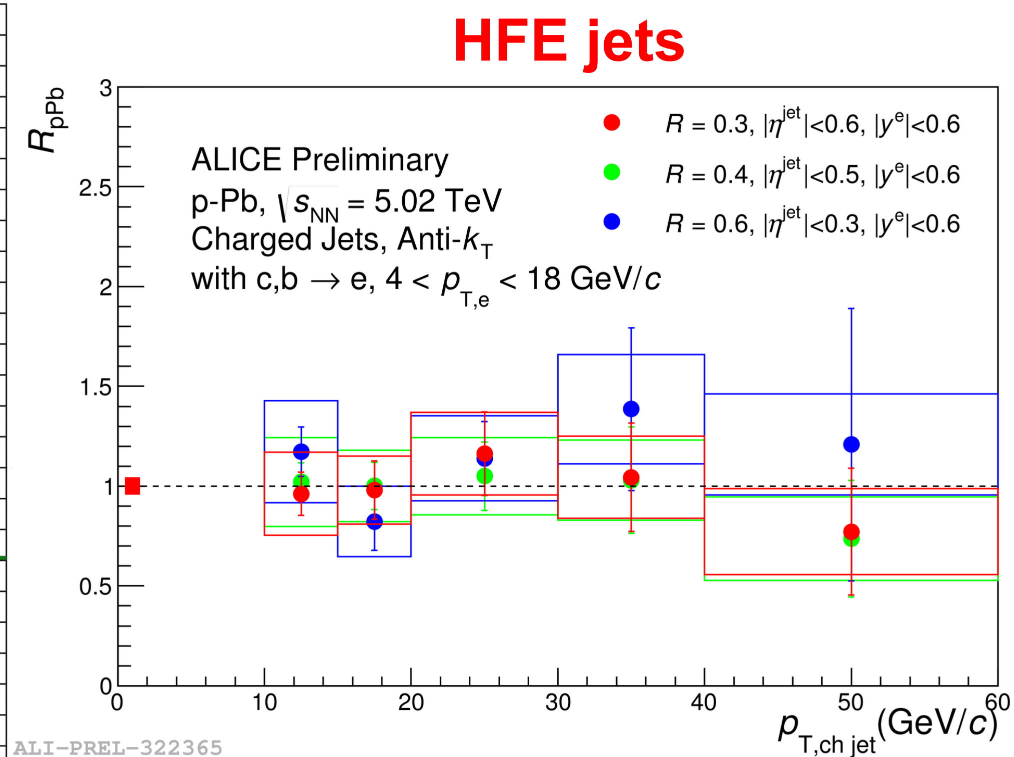
- Agreement with NLO pQCD POWHEG+PYTHIA simulation

Nuclear modification factor

$$R_{\mathrm{pA}}(p_{\mathrm{T}}) = \frac{1}{A}\frac{d\sigma_{\mathrm{pA}}/dp_{\mathrm{T}}}{d\sigma_{\mathrm{pp}}/dp_{\mathrm{T}}}$$

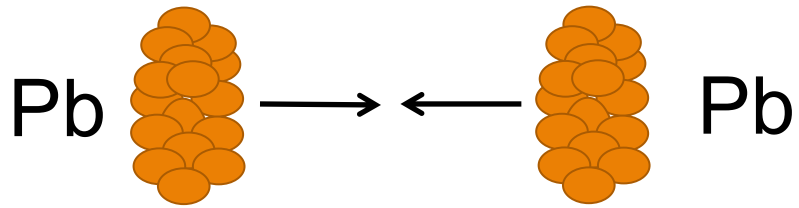
Ratio of the yield in p-Pb collisions to the binary scaled pp yield





- $R_{\text{p-Pb}}$ compatible with unity → no evidence of CNM effects

What have we learnt in Pb-Pb collisions?



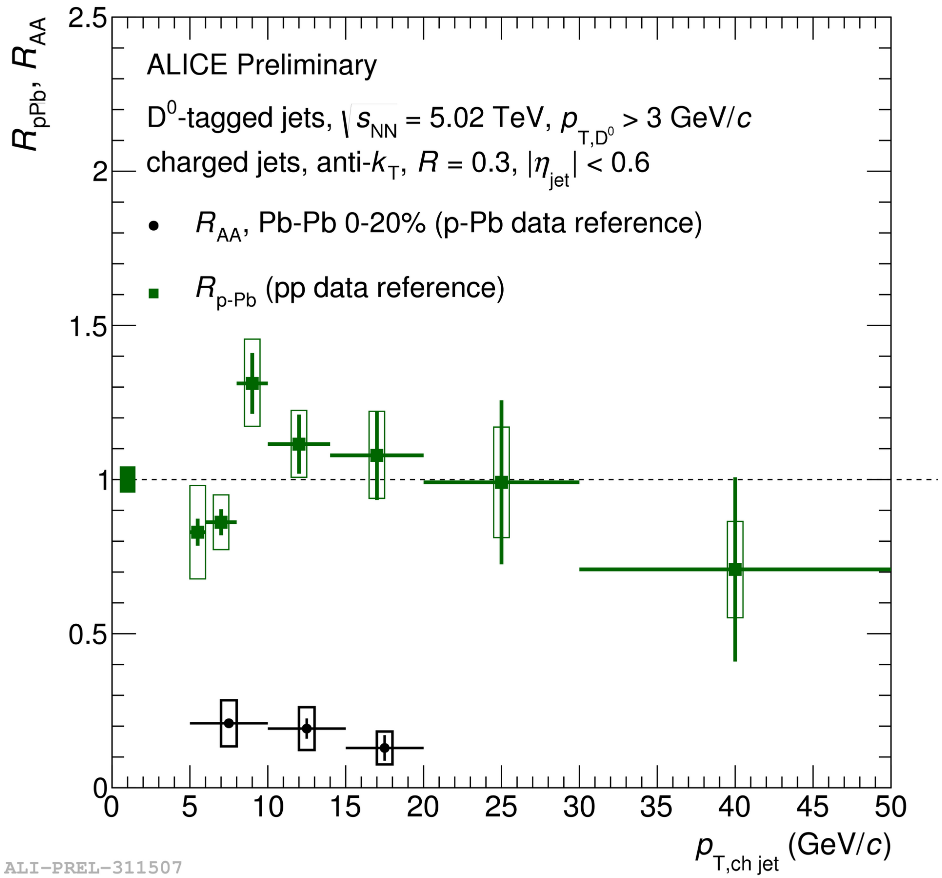
Physics motivations:

- Color and mass dependence of the in-medium energy loss
- Modification of the internal jet substructure

Nuclear modification factor

$$R_{AA}(p_T) = \frac{1}{\langle N_{coll} \rangle} \frac{\text{Yield in AA}}{\text{Yield in pp}}$$

D⁰ jets



- RAA < 1 and $R_{p\text{-}Pb}$ compatible with unity → strong suppression of the D^0-tagged jets in central Pb-Pb collisions

Conclusions and Outlook

Conclusions:

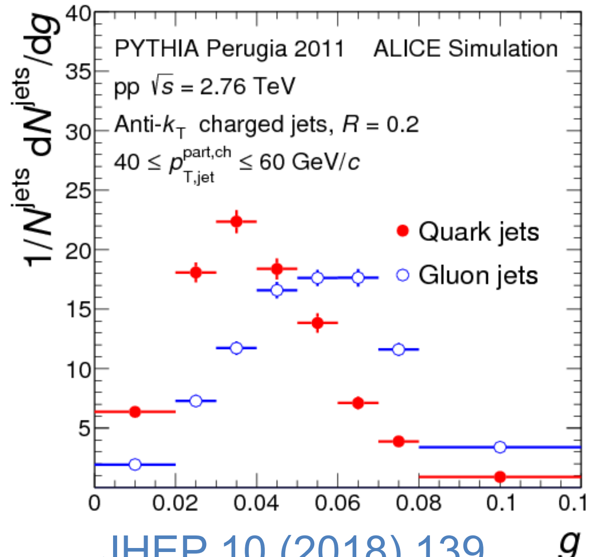
- p_T-differential cross sections of HFE and D^0-tagged jets in pp and p-Pb in agreement with POWHEG+PYTHIA predictions
- Hint of a softer fragmentation for higher p_T D^0-tagged jets
- Strong suppression of D^0-tagged jets in central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV in 5 < jet p_T < 20 GeV/c

Outlook:

- Complementary measurements to investigate the energy redistribution in the jet cone and difference between quark and gluon jets.
- For instance, angularity (g) is sensitive to the radial jet energy profile

$$g = \sum_{i \in \mathrm{jet}} \frac{p_{\mathrm{T}}^{i}}{p_{\mathrm{T}}^{\mathrm{jet}}} \Delta R_{\mathrm{jet,i}}$$

inclusive charged jets



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