Production of muons from heavy-flavour hadron decays in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE at the LHC

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Motivation

Heavy quarks (charm and beauty) in AA collisions

- **Produced in initial hard scatterings**
- **Experience the full evolution of the medium, interacting with the medium constituents**
- **Sensitive probes of the medium properties**

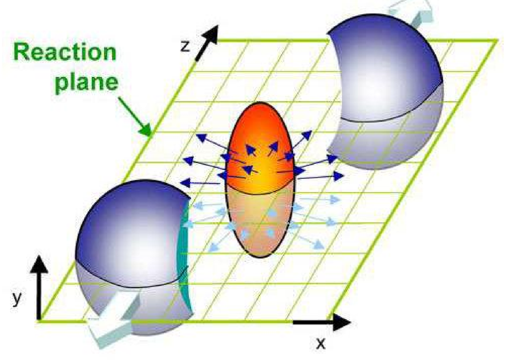
Investigate hot nuclear matter effects

- Energy loss in the medium via gluon radiation and elastic collisions: colour-charge and quark-mass dependence
- Participation in the collective expansion of the system

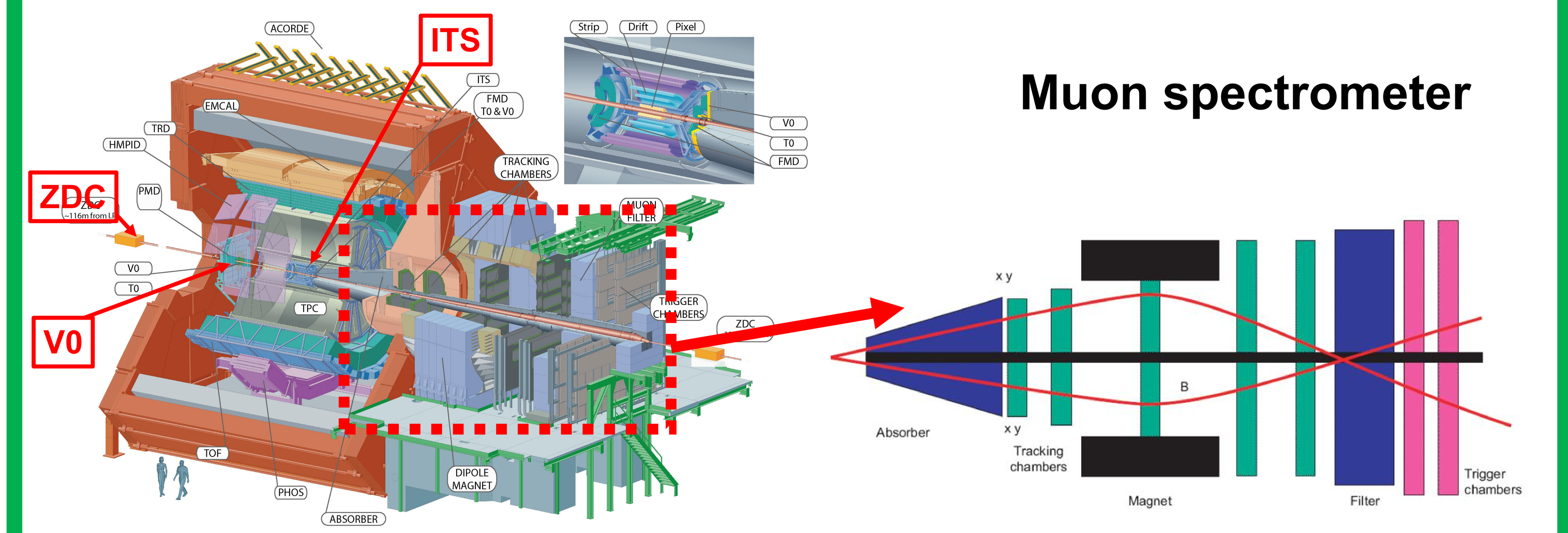
Observables

- **Nuclear modification factor R_{AA} :** $R_{AA}(p_T) = \frac{1}{<T_{AA}>} \times \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T}$
- **Azimuthal anisotropy:** $\frac{2\pi}{N}\frac{dN}{d\varphi} = 1 + \sum_{n=1}^{\infty} 2v_n \cos[n(\varphi-\psi_n)]$

  with elliptic flow v_2: $v_2 = <\cos[2(\varphi-\psi_n)]>$



ALICE detector



Muon spectrometer (-4 < η < -2.5) :

- Absorbers: front absorber, beam shield, muon filter
- Dipole magnet: 3 Tm field integral
- Trigger system: Resistive Plate Chambers
- Tracker system: Multi Wire Proportional Chambers with Cathode Pad Segmentation

V0 (2.8 < η < 5.1, -3.7 < η < -1.7): trigger, centrality determination

ITS ($|\eta|$ < 0.9): vertex determination

ZDC (4.8 < $|\eta|$ < 5.7): rejection of EM interaction, removal of beam-gas interactions

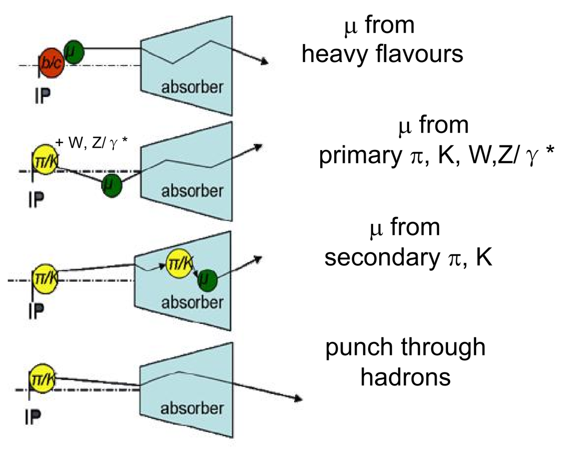
Data sample: Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV, 2015 run

Trigger condition: **signal in the two V0 arrays (minimum-bias trigger) with**

- at least one muon plus a low-p_T trigger threshold of ~ 1 GeV/*c* (L_{int} ≈ 21.9 μb^{-1}, 0-90% centrality class)
- at least one muon plus a high-p_T trigger threshold of ~ 4.2 GeV/*c* (L_{int} ≈ 202.3 μb^{-1}, 0-90% centrality class)

Track selection:

- **-4 < η < -2.5:** acceptance of the ALICE muon spectrometer
- **170° < θ_{abs} < 178°:** geometry of the spectrometer
- **muon trigger matching:** reject hadrons that cross the absorber
- **pointing angle to the vertex via *p* x DCA in 6σ:** remove beam-gas and particles produced in the absorber



Analysis Strategy

$$R_{AA} = \frac{1}{<T_{AA}>} \times \frac{dN_{AA}^{\text{inclusive } \mu}/dp_T - dN_{AA}^{\text{bkg}}/dp_T}{d\sigma_{pp}^{\mu \leftarrow HF}/dp_T}$$

Normalization

- Normalization of muon-trigger event sample to equivalent number of minimum bias events on a run by run basis

Acceptance times efficiency correction

- From simulations using NLO pQCD calculation of heavy-flavour signal production as input
- Centrality dependence of tracking efficiency estimated via embedding procedure, ~6% difference from 60-80% to 0-10% centrality class
- Systematic uncertainty on misalignment 0.5% x p_T (in GeV/*c*)

pp reference

- **p_T-differential cross section of heavy-flavour decay muons in 3 < p_T < 12 GeV/*c*:** p_T-differential cross section of heavy-flavour decay muons at $\sqrt{s}$ = 7 TeV measured in 3 < p_T < 12 GeV/*c* (PLB 708 (2012) 265) scaled to $\sqrt{s}$ = 5.02 TeV with FONLL (M.Cacciari et al., JHEP 10 (2012) 137; R. Averbeck et al., arXiv: 1107.3243)
- **p_T-differential cross section of heavy-flavour decay muons in 12 < p_T < 20 GeV/*c*:** scaling of FONLL cross section according to ratio between data (extrpolated to $\sqrt{s}$ = 5.02 TeV) & FONLL at lower p_T
- **Total systematic uncertainty:** systematic uncertainty in 3 < p_T < 12 GeV/*c*: 9-15% (data and energy scaling), systematic uncertainty in 12 < p_T < 20 GeV/*c*: 20-21% (FONLL and fit)

Background subtraction

$\mu \leftarrow \pi$, K (dominant background contribution at low/intermediate p_T) :

- Estimate π, K spectra at mid-rapidity in Pb-Pb collisions at 5.02 TeV

$$\frac{dN_{AA,5.02TeV}^{K,\pi}}{dp_T} = \frac{dN_{AA,5.02TeV}^{ch}/dp_T}{dN_{AA,2.76TeV}^{ch}/dp_T} \times \frac{dN_{AA,2.76TeV}^{K,\pi}}{dp_T}$$

- Then, estimate π, K spectra in Pb–Pb collisions at forward rapidity via

$$\frac{1}{N_{ev}}\frac{d^2N_{AA}^{K/\pi}}{dp_T dy} = n_y \times \frac{1}{N_{ev}}\frac{dN_{AA}^{K/\pi}}{dp_T}\Big|_{|y|<0.8} \times \exp\left(\frac{-y^2}{2\sigma_y^2}\right)$$

  - ✓ with σ_y estimated from PYTHIA and PHOJET (extrapolation of mid-rapidity π, K spectra in pp collisions towards forward rapidity)
  - ✓ varying n_y to estimate the systematic uncertainty on unknown quenching effect at forward rapidity
- Produce the π, K decay muon background in Monte-Carlo with fast simulation taking into account detector properties as previously done (Phys. Rev. Lett. 109 (2012) 112301)
- Contribution: ~16% (10%) in 0-10% (60-80%) centrality class at p_T = 3 GeV/*c*

$\mu \leftarrow$ W, Z/γ * (dominant background contribution at high p_T) :

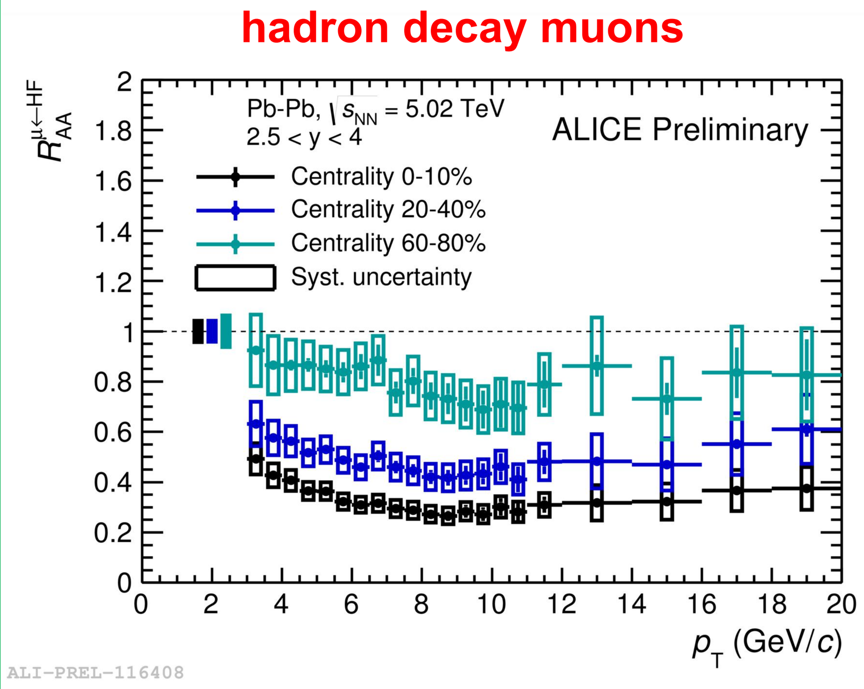
- Subtraction with templates obtained by combining pp, pn, np, and nn cross sections estimated with POWHEG simulations, properly scaled for Pb-Pb collisions

$$\frac{d\sigma_{Pb-Pb}}{dp_T} = \frac{Z^2}{A^2} \times \frac{d\sigma_{pp}}{dp_T} + \frac{(A-Z)^2}{A^2} \times \frac{d\sigma_{nn}}{dp_T} + \frac{Z\cdot(A-Z)}{A^2}\left\{\frac{d\sigma_{pn}}{dp_T} + \frac{d\sigma_{np}}{dp_T}\right\} \quad \text{(A = 208, Z = 82)}$$

- Contribution: ~38% (19%) in 0-10% (60-80%) centrality class at p_T = 20 GeV/*c*

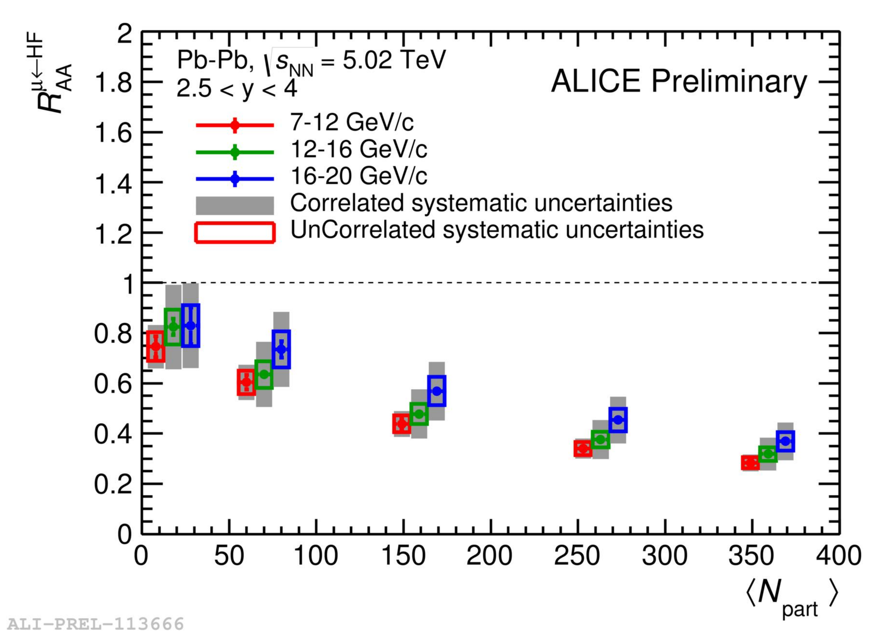
Results

p_T-differential R_{AA} of heavy-flavour hadron decay muons



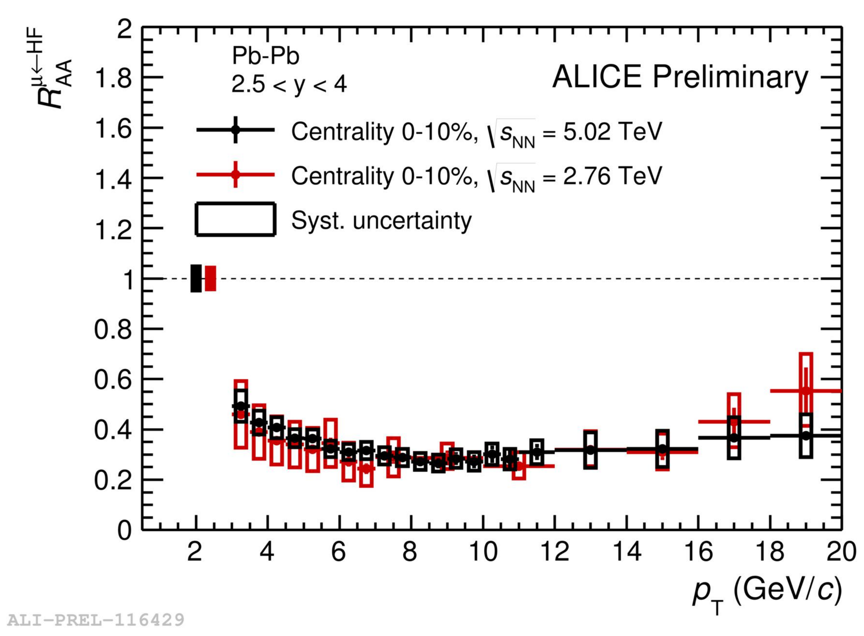
- Suppression of heavy-flavour hadron decay muon yields in various centrality classes
- Clear increase of the suppression for more central events: about a factor three in 0-10% for 7 < p_T < 12 GeV/*c*

Centrality dependence of the heavy-flavour hadron decay muon R_{AA}



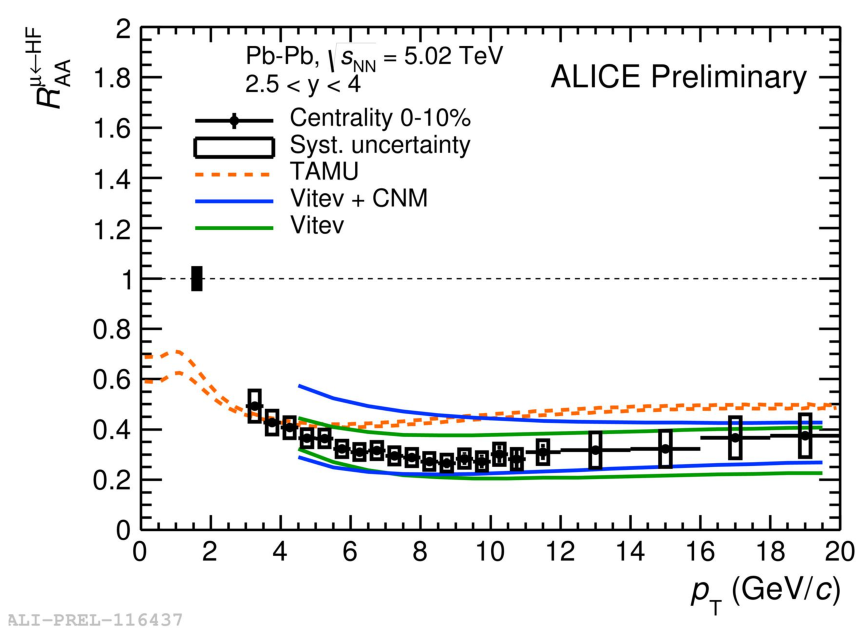
- The suppression increases from peripheral to central collisions
- No evident p_T dependence within uncertainties for 7 < p_T < 20 GeV/*c*
- In 7 < p_T < 20 GeV/*c*, beauty contribution is dominant in pp collisions at $\sqrt{s}$ = 5 TeV according to FONLL calculations

Comparison with the measurement at $\sqrt{s_{NN}}$ = 2.76 TeV



- Similar suppression at forward rapidity at $\sqrt{s_{NN}}$ = 5.02 TeV and $\sqrt{s_{NN}}$ = 2.76 TeV for central collisions within uncertainties
- New measurement at $\sqrt{s_{NN}}$ = 5.02 TeV has significantly smaller uncertainties

Comparison with model predictions



- R_{AA} measurements at $\sqrt{s_{NN}}$ = 5.02 TeV provide new and stringent constraints on energy loss models

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Outlook: measurement of heavy-flavour hadron decay muons in pp colllisions at $\sqrt{s}$ = 5.02 TeV

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