# Experimental Overview: the Results of Heavy Flavours at LHC in QM 2018

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# Outline

# The evolution of heavy flavours

→ **Charm and beauty** quarks are produced in **hard scattering processes** in the initial stages of the collisions

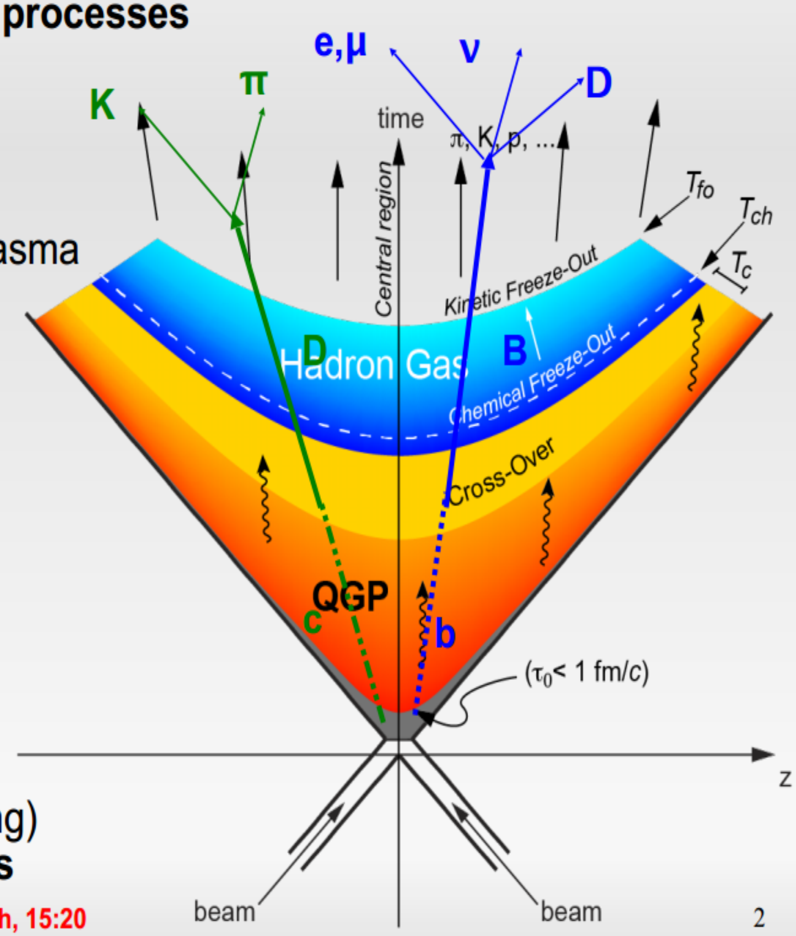
→ They experience the full evolution of the system
→ sensitive probes of the properties of the Quark-Gluon Plasma

→ Expected to **lose energy** while traversing the medium

→ **Collective expansion** of the medium

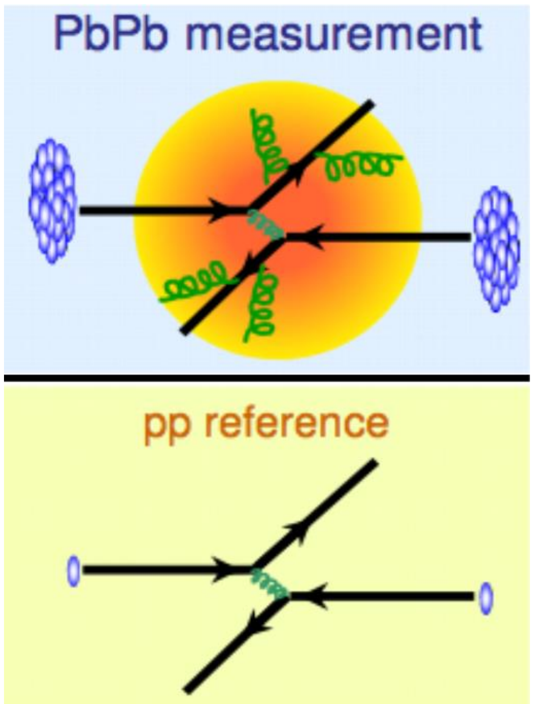
→ **Hadronization**: fragmentation vs coalescence

→ **Cold Nuclear Matter effect**: modification of nPDF (shadowing)
- Need **reference measurements in pp and p-Pb collisions**




H. Zanoli: Wed 16th, 15:20

# Nuclear modification factor : $R_{AA}$




$$R_{AA}(p_T) = \frac{dN_{AA} / dp_T}{\langle T_{AA} \rangle \times d\sigma_{pp} / dp_T}$$

A-A

pp

Nuclear overlap function, encodes collision geometry

If $R_{AA}=1$ → no nuclear effects

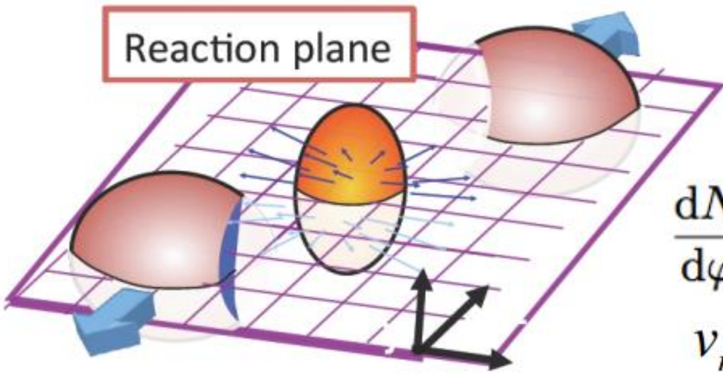
If $R_{AA}\neq 1$ → nuclear effects

**Never forget:**

$\frac{dN_{AA}}{dp_T}$ = "vacuum" parton spectra | initial-state effects | parton interaction with the medium | (modified?) hadronization | hadronic phase | decay kinematics e.g. for leptons

# Introduction

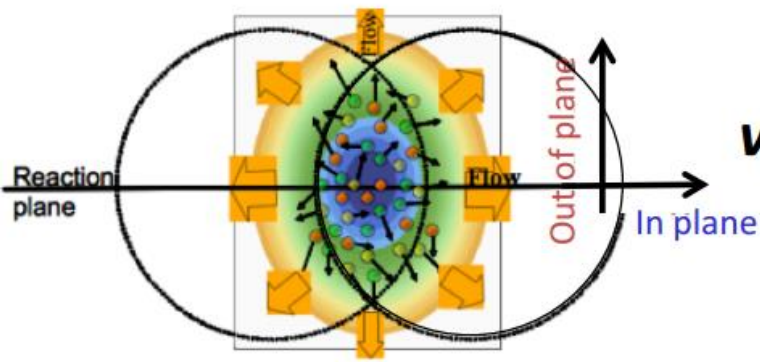
## Azimuthal anisotropy--elliptic flow : $V_2$




Initial spatial anisotropy → momentum anisotropy

$$\frac{dN}{d\varphi} = \frac{N_0}{2\pi}\left(1 + 2v_1\cos(\varphi-\Psi_1) + 2v_2\cos[2(\varphi-\Psi_2)] + \dots\right)$$

$$v_n = \langle \cos(n[\varphi-\psi_n]) \rangle$$




$v_2>0$

→ Thermalization/collective motion (at low $p_T$)

→ Path length dependence of energy loss (at high $p_T$)

# Introduction

## Quarkonium and heavy meson

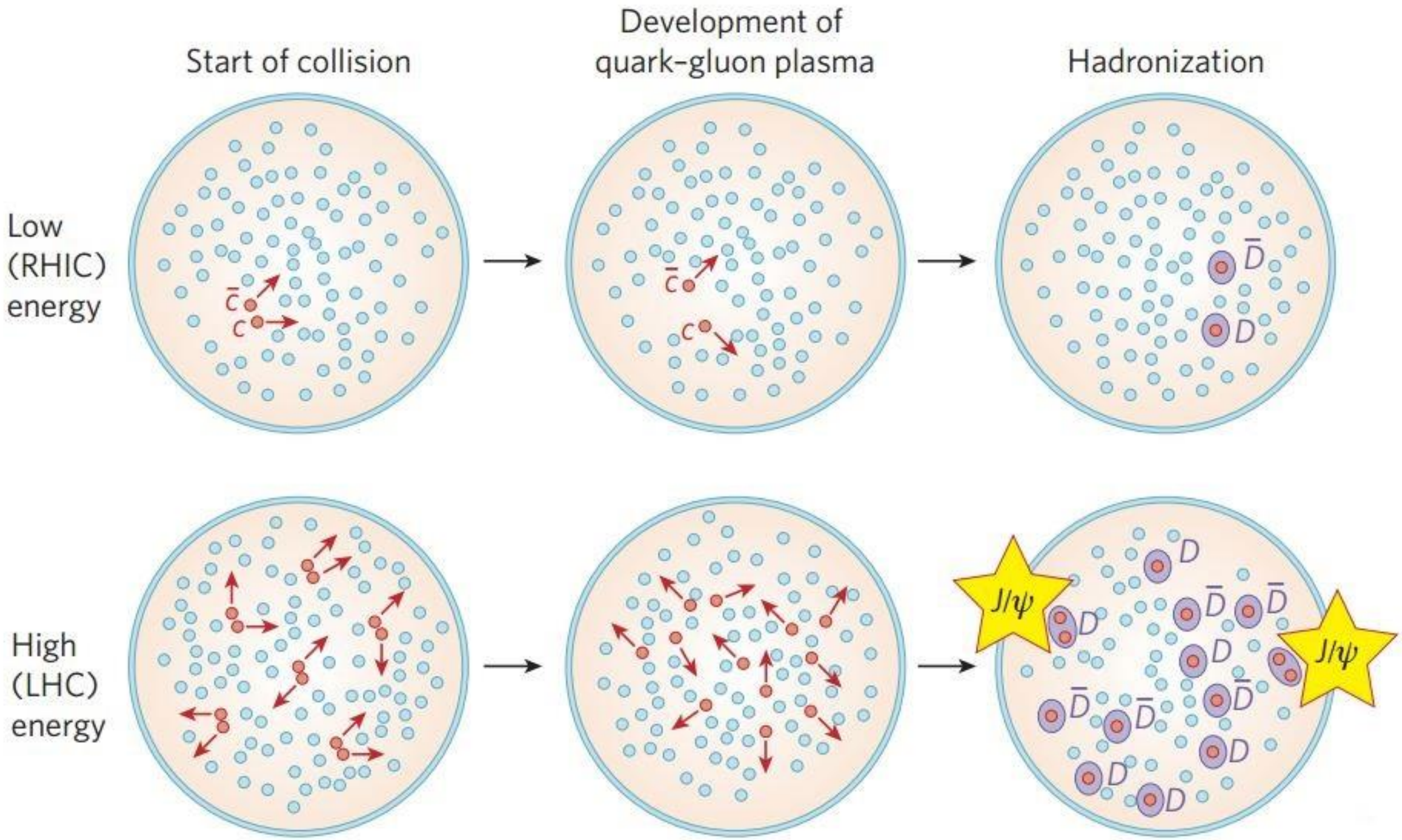
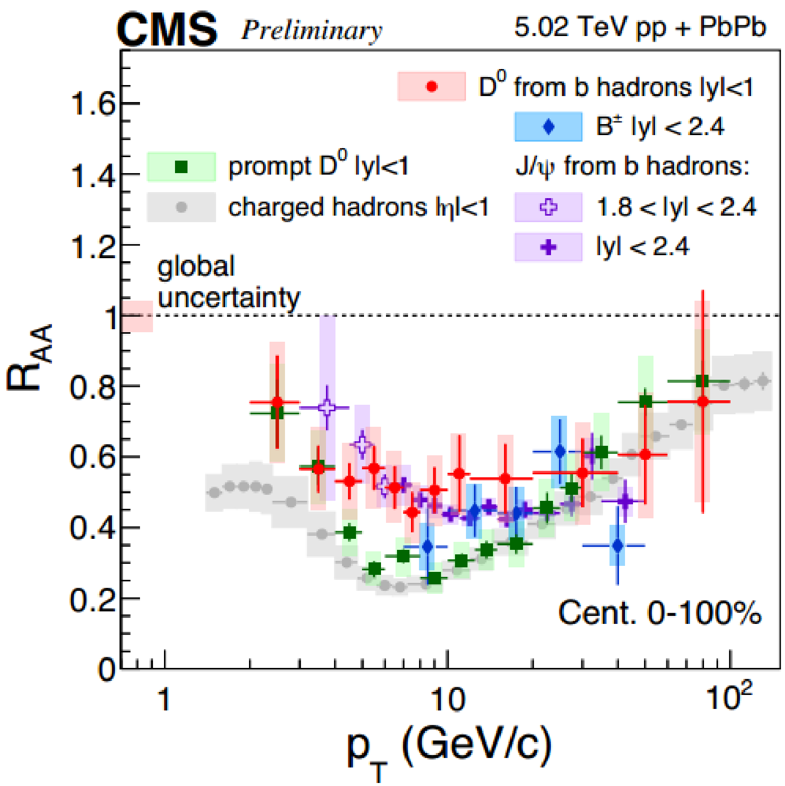



*Figure: P. Braun-Munzinger, J. Stachel, Nature 448 (2007) 302*

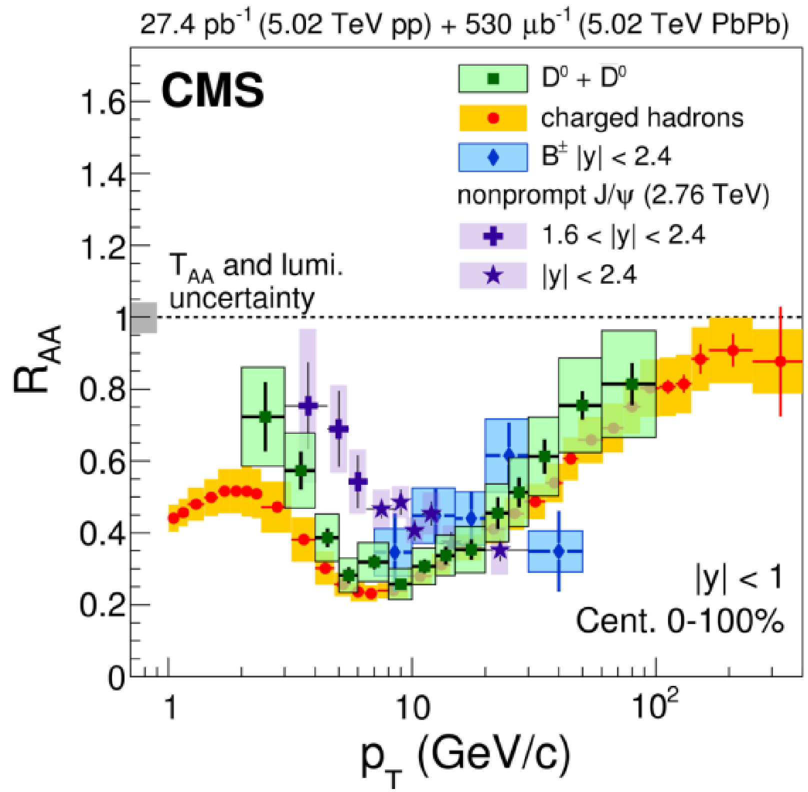
# Open Heavy Flavours in Nucleus-Nucleus Collisions

# Open Heavy Flavour in Nucleus-Nucleus Collisions

## $R_{AA}$ in Pb-Pb collision




arXiv:1712.08959



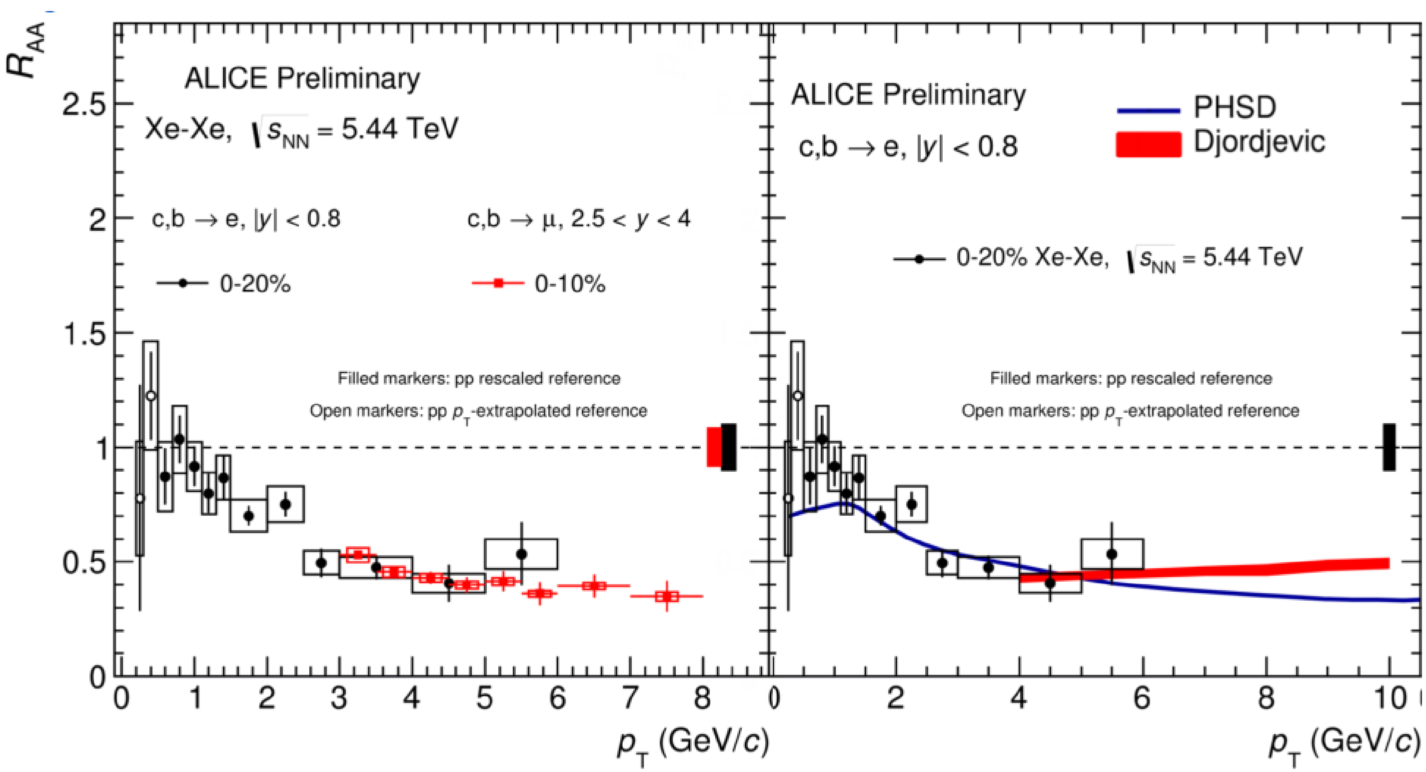

**CMS HIN-16-001**

arxiv: 1708.04962

**First** measurement of non-prompt $D_0$ $R_{AA}$

$D_0$ from b hadron

# $R_{AA}$ in Xe-Xe collision

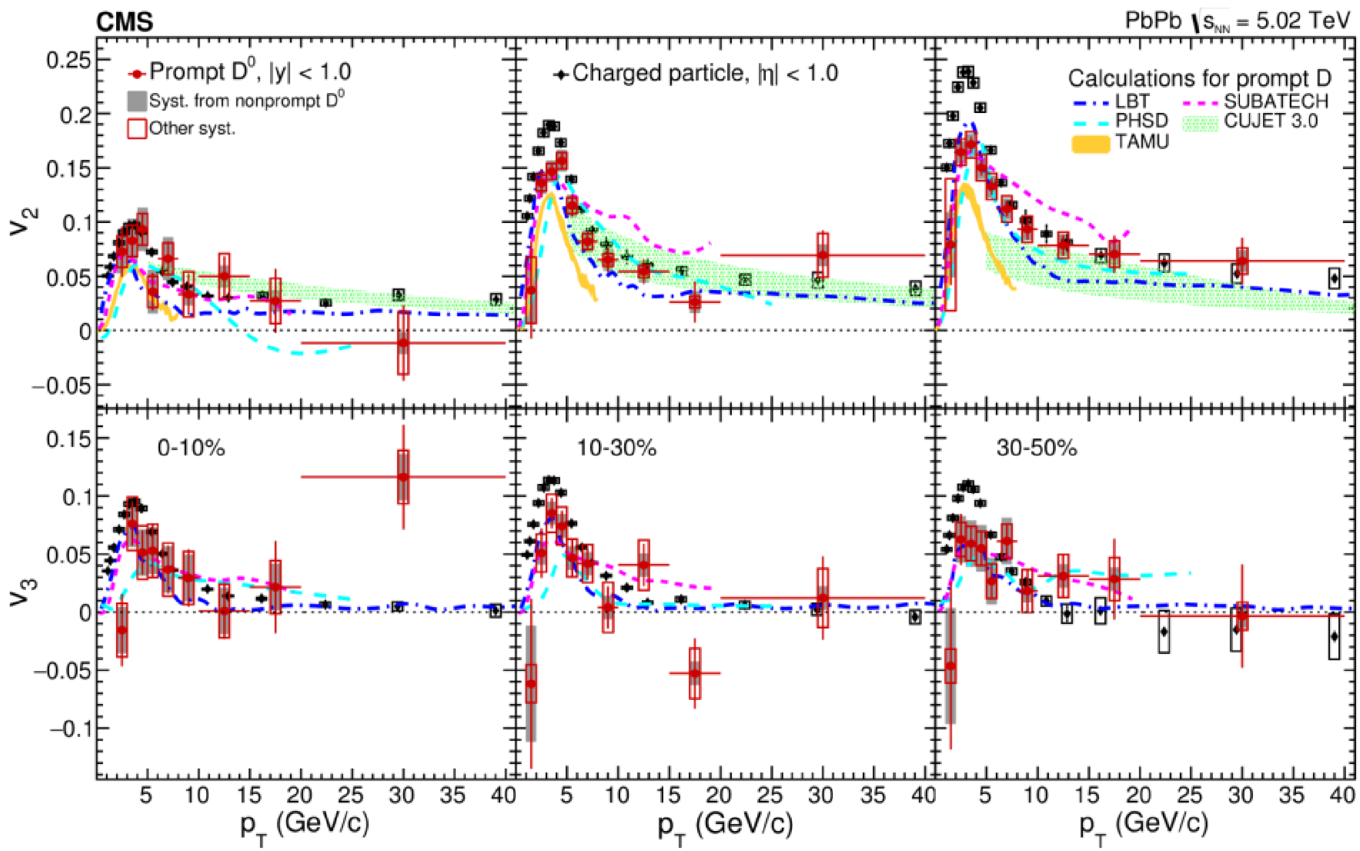



$R_{AA}$ of heavy-flavor electrons and muons in Xe-Xe collisions at 5.44TeV

# Open Heavy Flavour in Nucleus-Nucleus Collisions

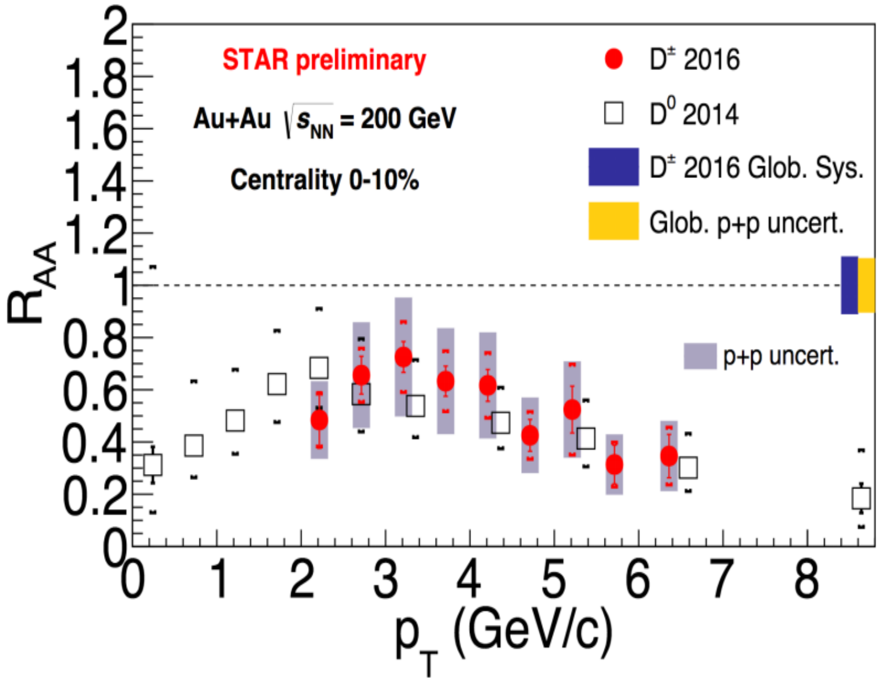
## Flow of D0 in Xe-Xe collision

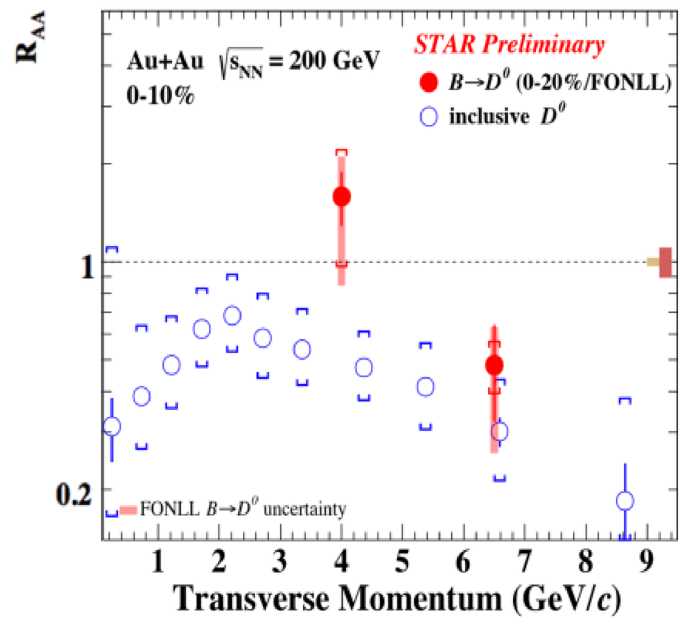
**CMS HIN-16-007**
arxiv: 1708.03497




D0 meson V2 and V3 in PbPb Collisions and Comparison with Theoretical Models

# $R_{AA}$ of D meson at RHIC



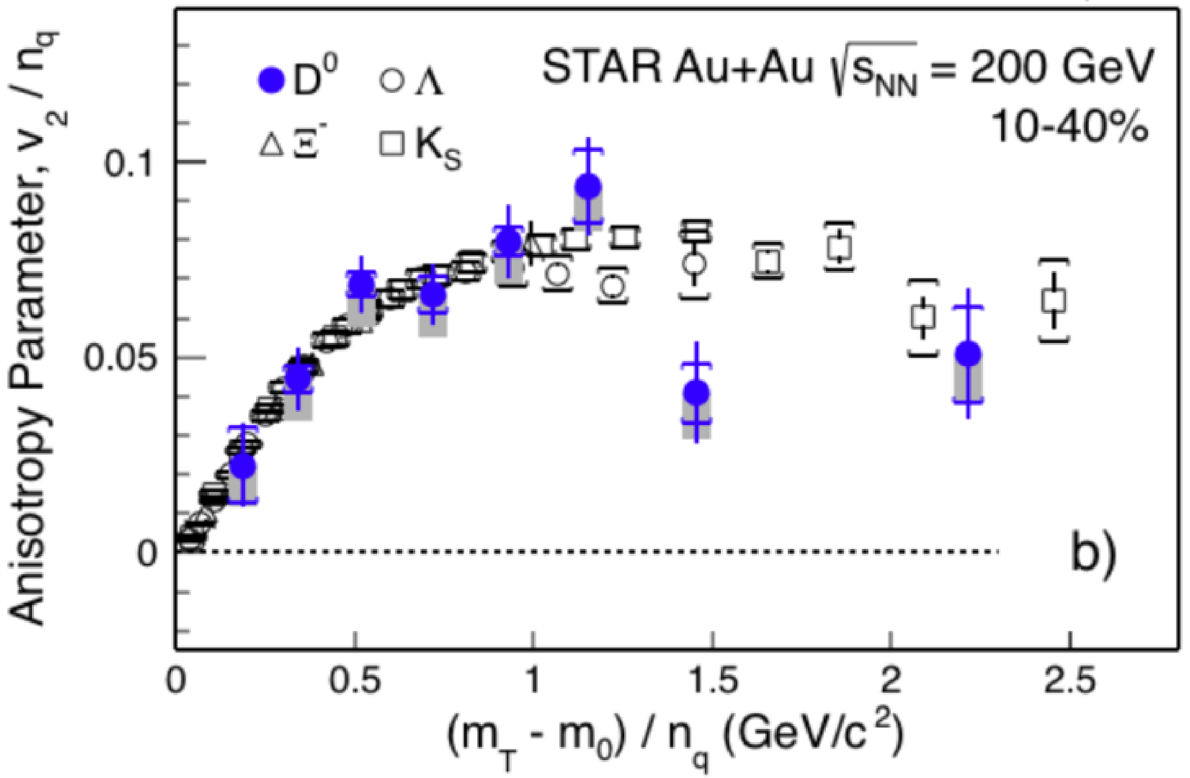




- Similar suppression for $D^0$ and $D^{+/-}$
- Spectra measurements important for total charm cross-section

- $R_{AA}$ of B mesons estimated from the measured non-prompt $D^0$ fraction

# $V_2$ of D meson at RHIC

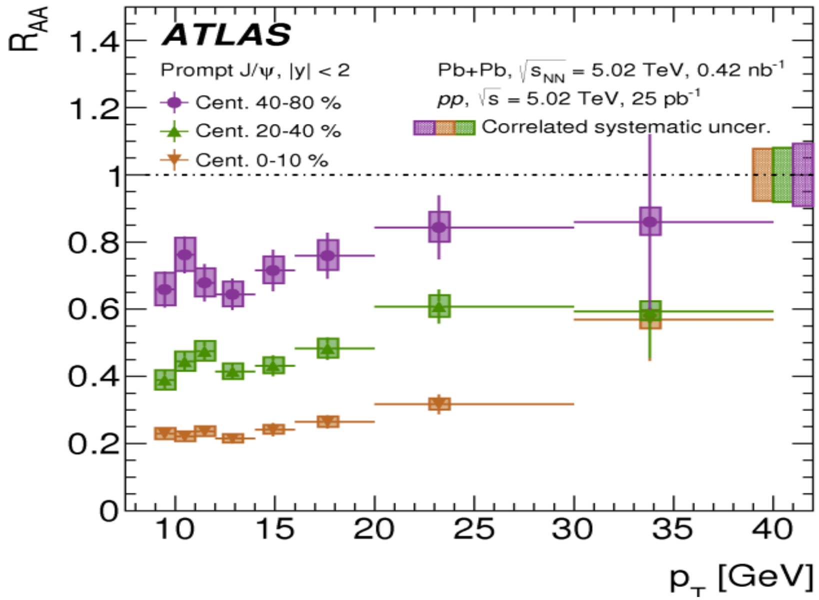
*Phys. Rev. Lett. 118 (2017) 212301*

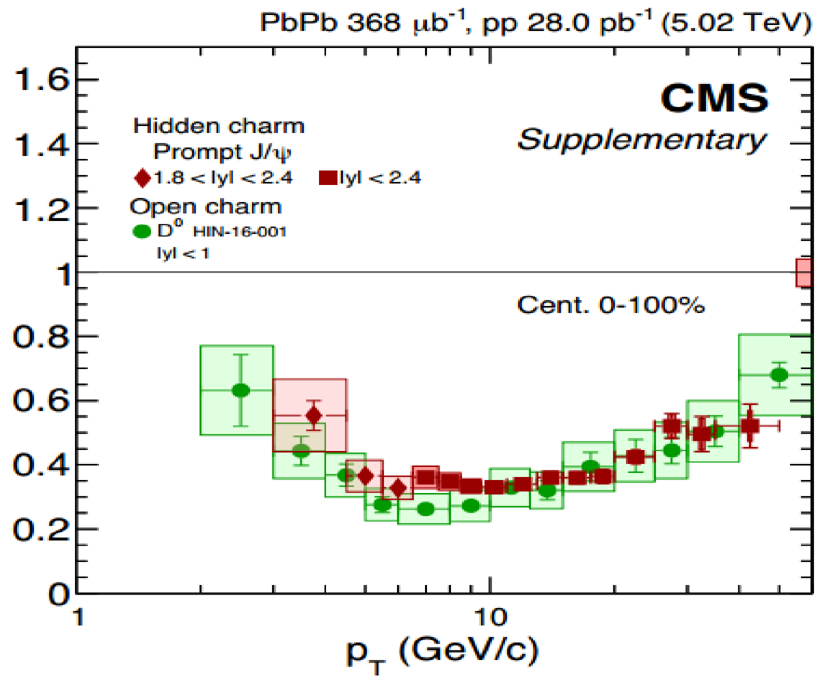



Charm quarks seem to acquire the same flow as light quarks!

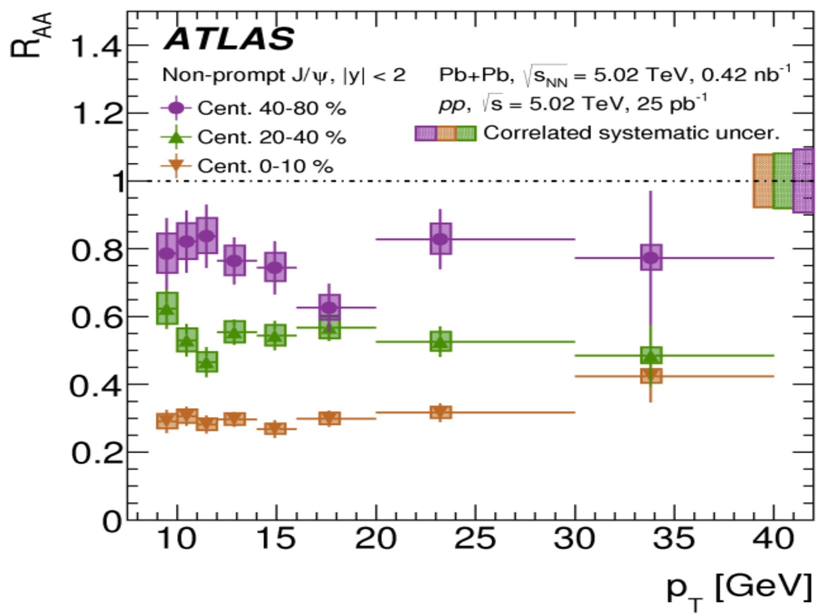
# Quarkonium in Nucleus-Nucleus Collisions

# Quarkonia in Nucleus-Nucleus Collisions



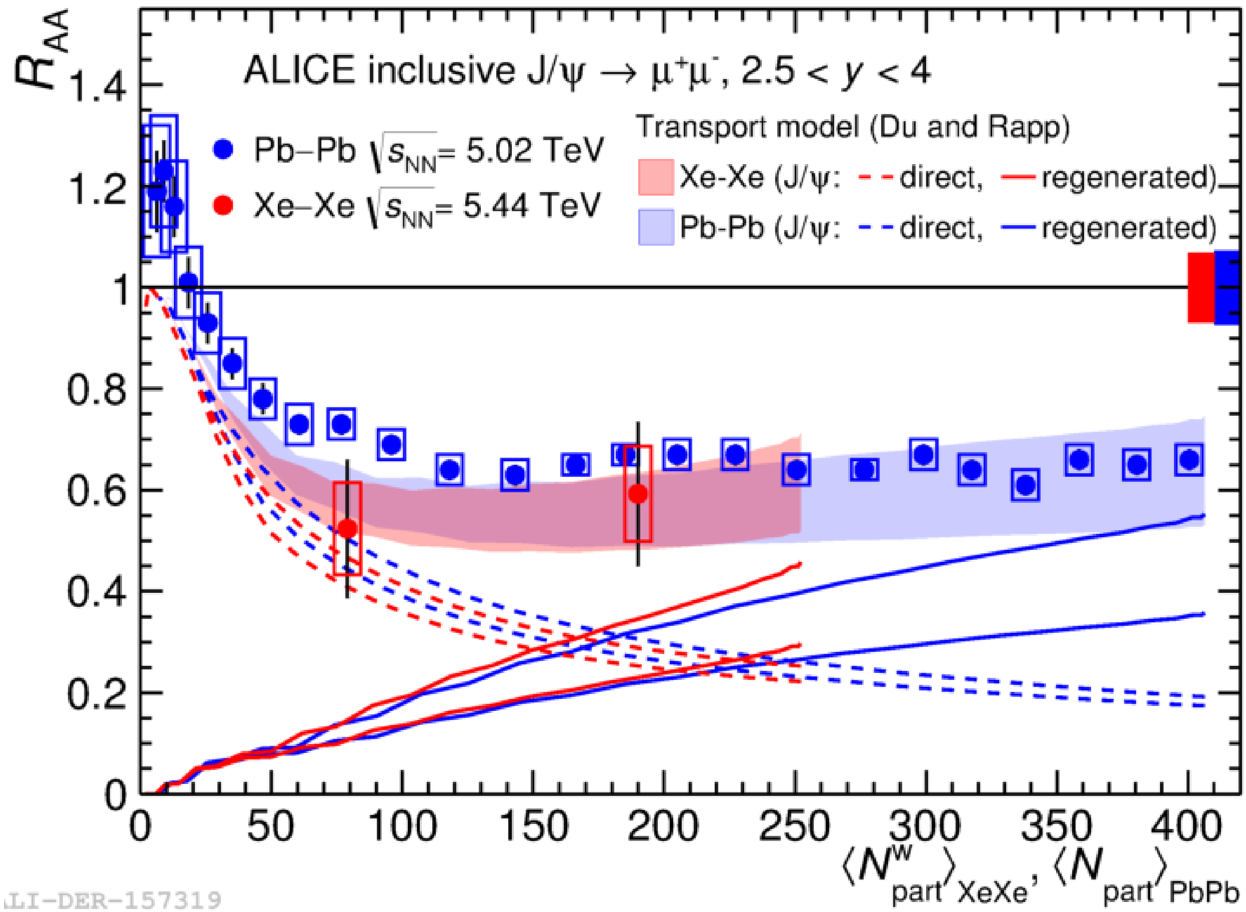

arXiv:1712.08959




RAA of J/psi in PbPb at 5.02TeV

arXiv:1805.04077

# Quarkonia in Nucleus-Nucleus Collisions

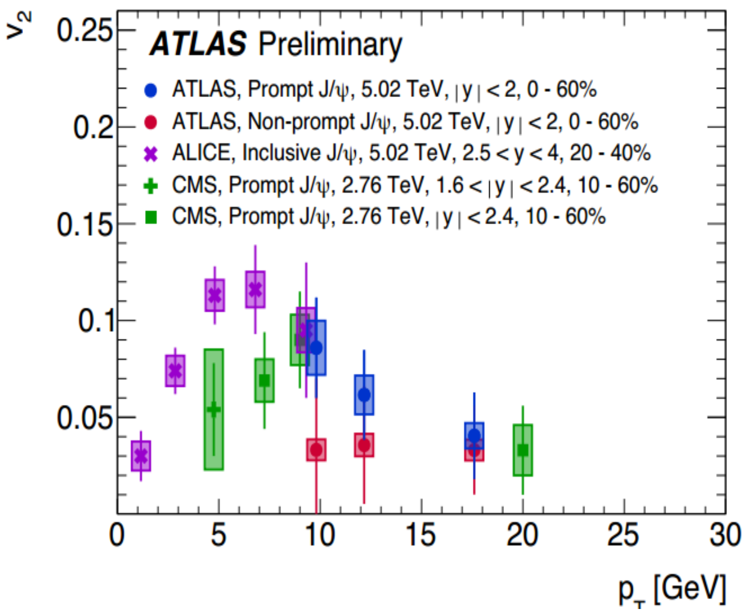



arXiv:1805.04383

Transport models predict a slightly stronger suppression in Xe-Xe collisions, counterbalanced by a larger recombination effect

# Quarkonia in Nucleus-Nucleus Collisions

## Elliptic flow :$V_2$

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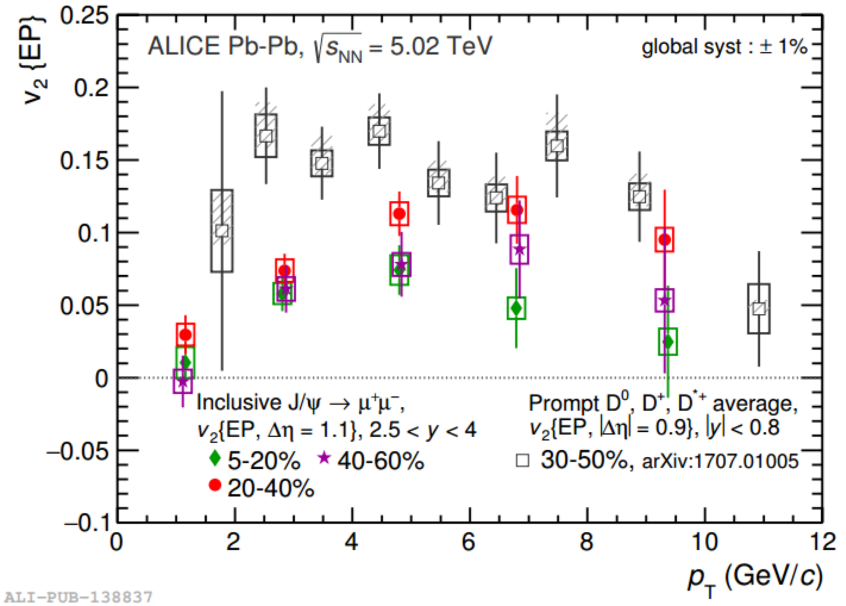
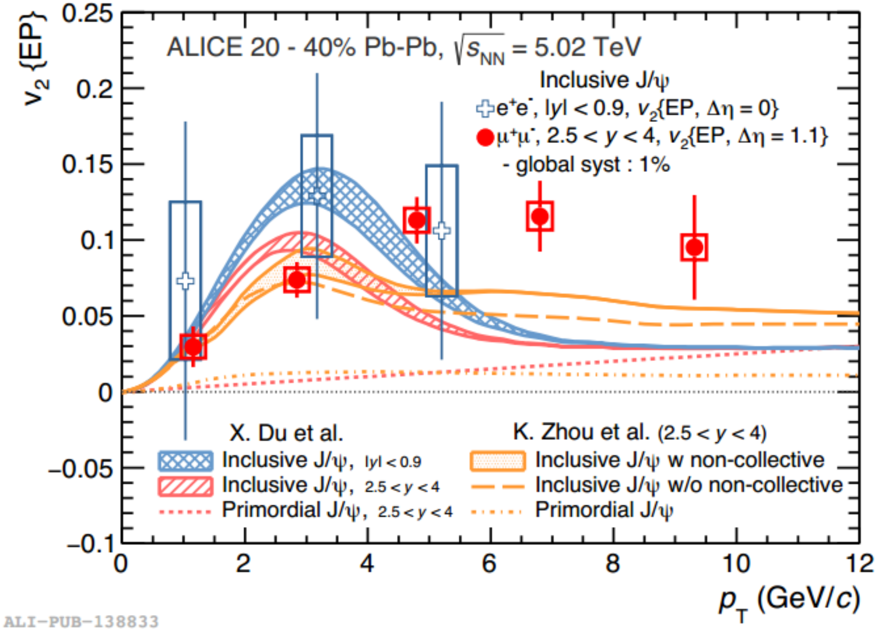



*ALICE Collaboration PRL 119 (2017) 242301*
*ALICE Collaboration PRL 120 (2018) 102301*

# Theoretical description for $V_2$

- forward and mid-rapidity results agree within uncertainties
- at low $p_T$ models including regeneration agree with the data
- at high $p_T$ the elliptic flow is underestimated by the models




*ALICE Collaboration PRL 119 (2017) 242301*

# Cold Nuclear Matter Effects in Heavy Flavours

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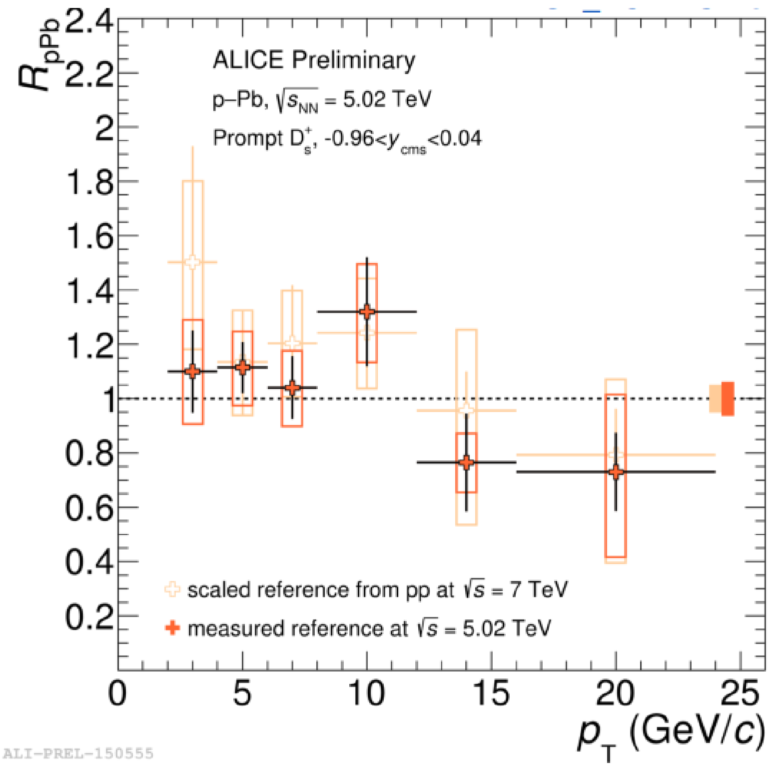
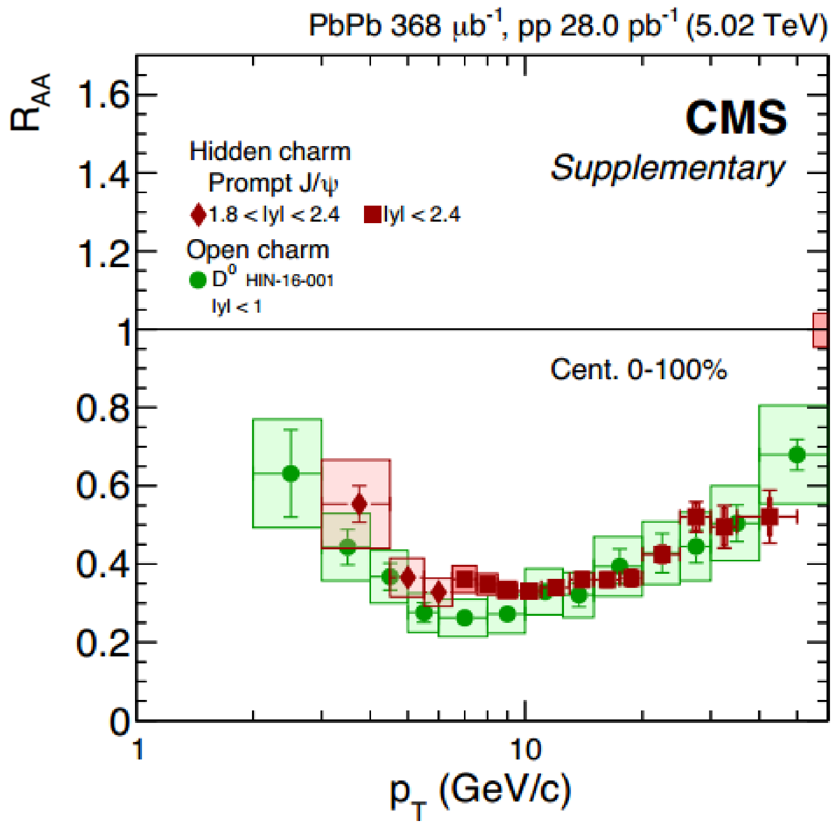
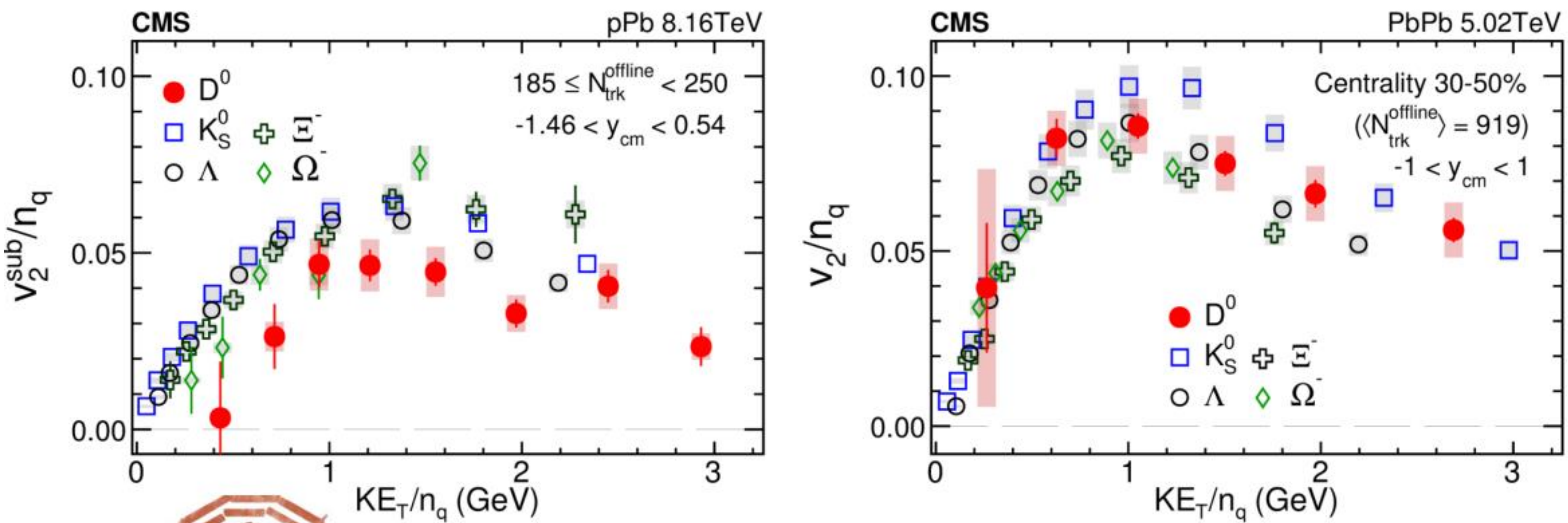



ALICE_PUBLIC-2018-006

arXiv:1712.08959

# Cold Nuclear Matter Effect in Heavy Flavours




CMS NEW RESULT QM18

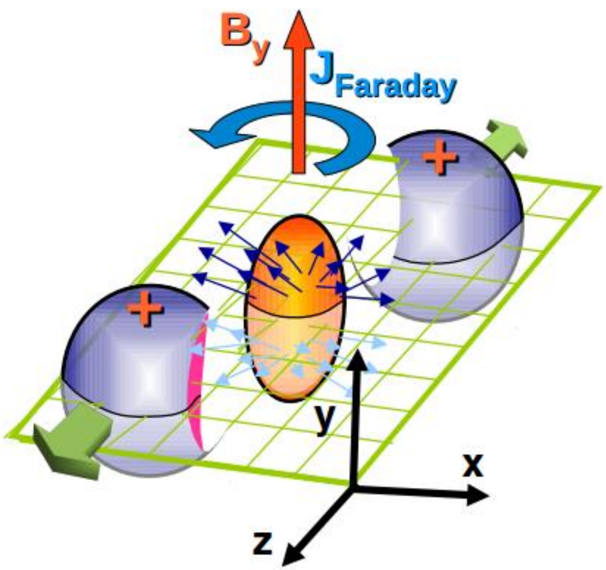
arXiv: 1804.09767

- $v_2^{D^0} < v_2^{light\ hadrons}$
- Charm quarks does not couple to the system as strongly as the light flavor quarks
- $D^0\ v_2^{pPb} < v_2^{PbPb}$ for a given $p_T$

# Magnetic Vortical HQ Dynamics

Talk by **S. Plumari**

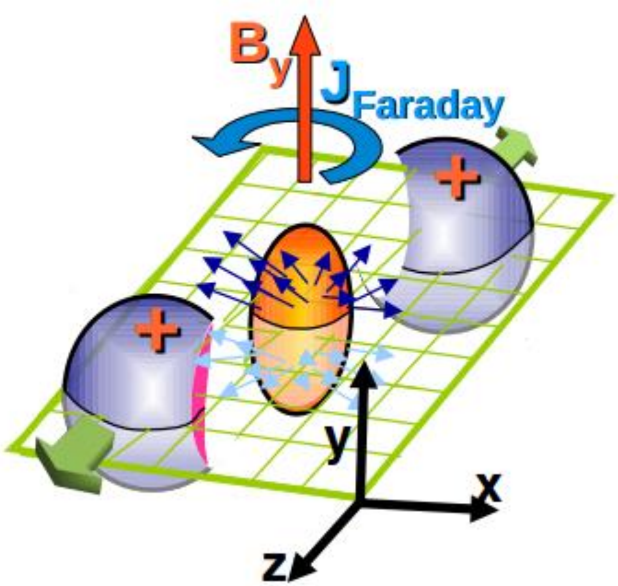
# Magnetic vortical HQ dynamics

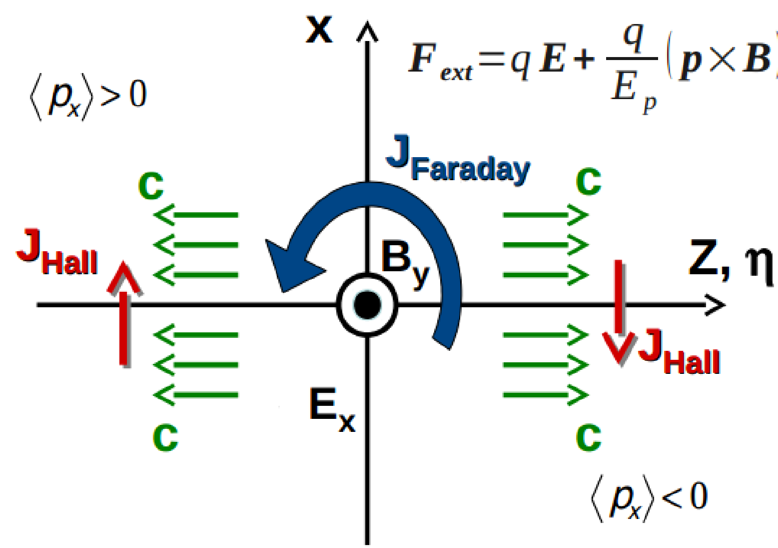



- **Intense magnetic field B:**
  - created on Earth ≈ $10^7$ Gauss
  - in Neutron Star ≈ $10^{13}$ Gauss
  - **in uRHIC ≈ $10^{19}$ Gauss ≈ 10 $m_\pi^2$**

A. Bzdak, V. Skokov, PLB **710** (2012) 171-174
K. Tuchin, PRC **88**, 024911 (2013).
K. Tuchin, Adv. High Energy Phys. 2013, 1 (2013).
K. Hattori, X.-G. Huang Nucl.Sci.Tech. 28 (2017) no.2, 26.

# Magnetic Vortical HQ Dynamics




$$v_1 = \left\langle \frac{p_x}{p_T} \right\rangle \neq 0$$

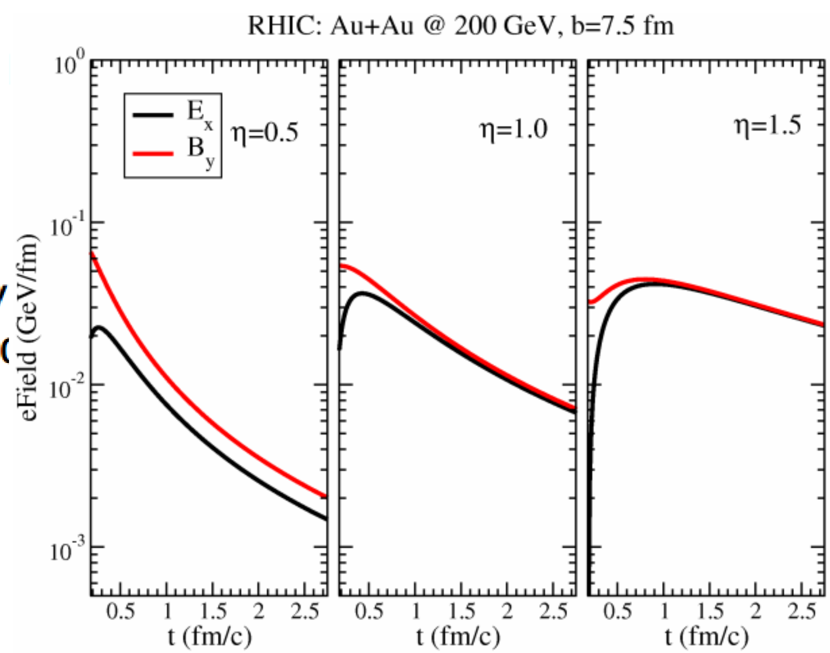
# Magnetic Vortical HQ Dynamics

Solve the Maxwell eq.s by starting with a point-like charge at the $\mathbf{x}_T$ in the transverse plane and moving in the +z direction with velocity $\boldsymbol{\beta}$.

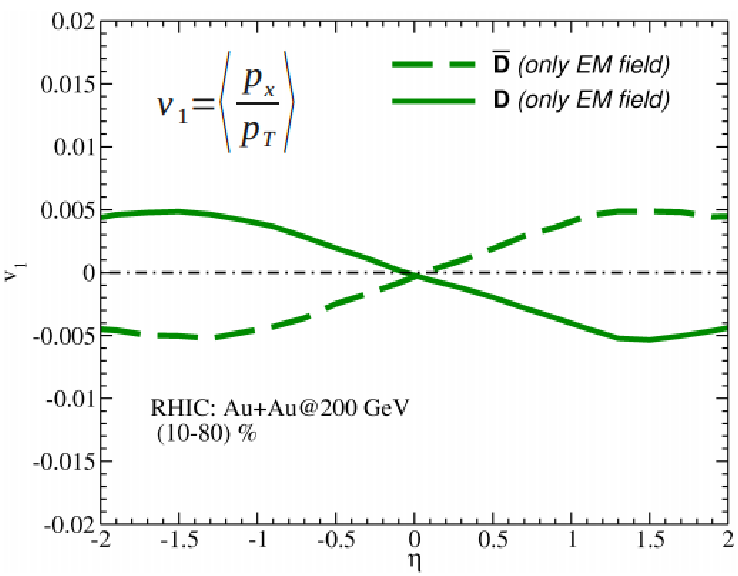
$$\begin{cases} \nabla\cdot\boldsymbol{E}=e\delta(z-\beta t)\delta(\boldsymbol{x}-\boldsymbol{x_T}) \\ \nabla\cdot\boldsymbol{B}=0 \qquad \nabla\times\boldsymbol{E}=-\dfrac{\partial\boldsymbol{B}}{\partial t} \\ \nabla\times\boldsymbol{B}=\dfrac{\partial\boldsymbol{E}}{\partial t}+\sigma_{el}\boldsymbol{E}+e\boldsymbol{\beta}\delta(z-\beta t)\delta(\boldsymbol{x}-\boldsymbol{x_T}) \end{cases}$$

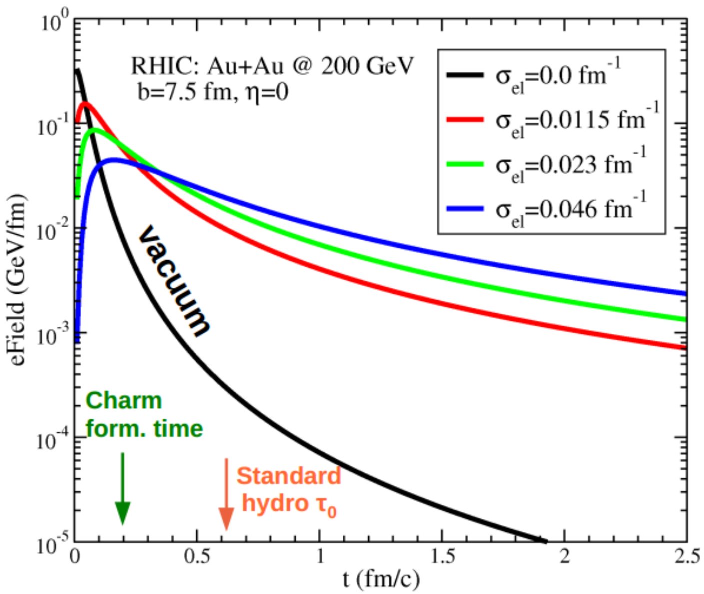
Fold them with the nuclear transverse density profile of the spectator nuclei and sum forward (+) and backward (-)

$$\begin{aligned} eB_{y,s} &= -Z\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} d\phi' \int_{x_{\rm in}(\phi')}^{x_{\rm out}(\phi')} dx'_\perp x'_\perp \rho_-(x'_\perp) \\ &\quad \times \left(eB_y^+(\tau,\eta,x_\perp,\pi-\phi)+eB_y^+(\tau,-\eta,x_\perp,\phi)\right) , \\ eE_{x,s} &= Z\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} d\phi' \int_{x_{\rm in}(\phi')}^{x_{\rm out}(\phi')} dx'_\perp x'_\perp \rho_-(x'_\perp) \\ &\quad \times \left(-eE_x^+(\tau,\eta,x_\perp,\pi-\phi)+eE_x^+(\tau,-\eta,x_\perp,\phi)\right) , \end{aligned}$$



# Magnetic Vortical HQ Dynamics




**For light quarks was predicted $v_1 \approx 10^{-3}$ -$10^{-4}$**

U. Gürsoy, D. Kharzeev, K. Rajagopal PRC 89, 054905 (2014).

**For charm quarks due to early production we find a sizeable $v_1$ with the same E-B evolution**

S. K. Das, S. Plumari, S. Chatterjee, J. Alam, F. Scardina, V. Greco, PLB768 (2017) 260-264.


Thank you !