Search for Electromagnetic Fields in PbPb Collisions at 5.02 TeV Measuring Azimuthal Anisotropy of Prompt D^0 Mesons

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for the CMS Collaboration

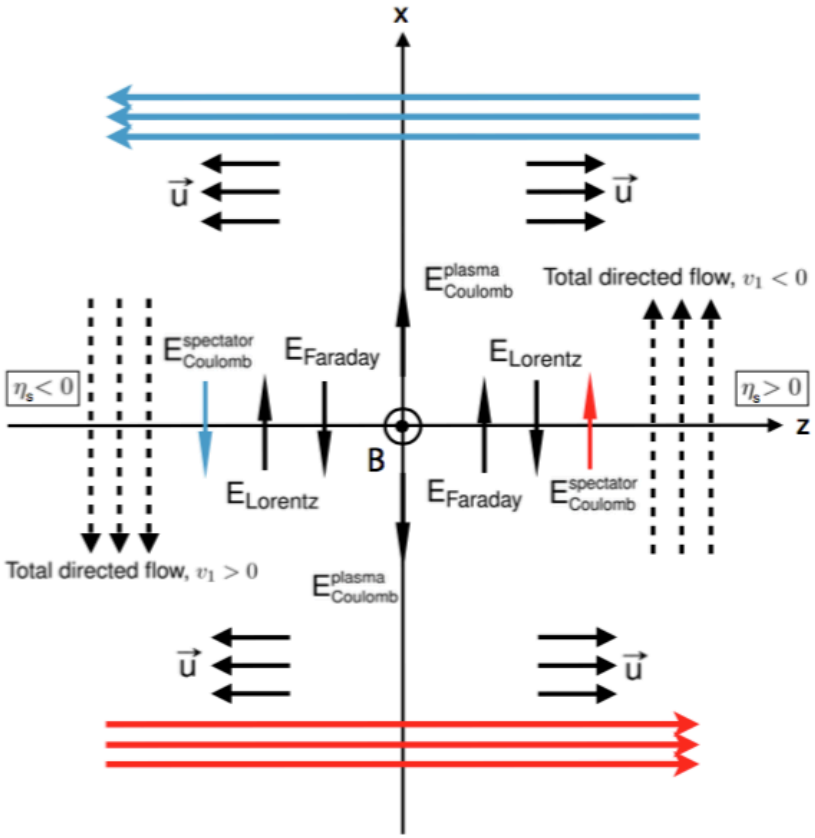
SPRACE

Electromagnetic Fields in PbPb Collisions

Phys. Rev. C **98**, 055201 (2018)

Strong and short lived EM fields in PbPb collisions at LHC

- Generated by spectators and participants
- Charge-odd contributions to flow coefficients (v_n)
  - Non-zero Δv_n for opposite-charge
- Measurements constrain medium parameters
  - E.g. electric conductivity



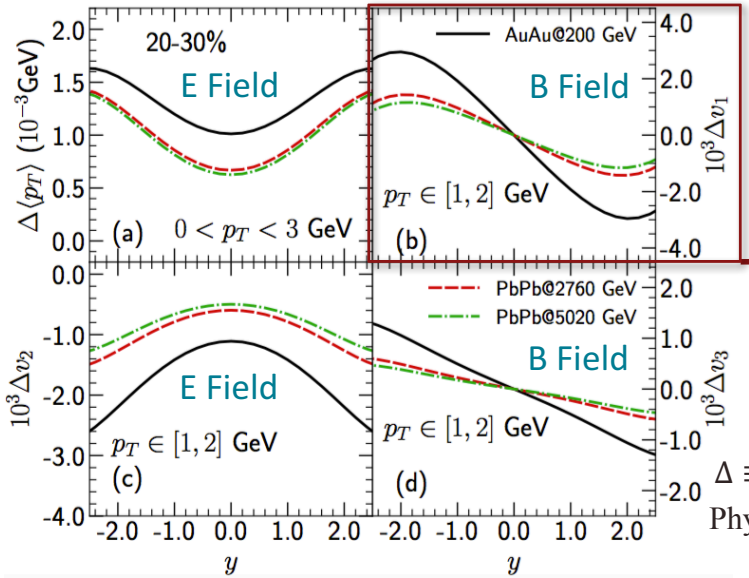
Effect on Δv_1 of D^0 Mesons

D^0 ($\bar{u}c$) produced in primordial stages of collision (~0.1 fm/c)

- m_{charm} >> typical medium temperatures: lower probability of annihilation

EM fields vanish very fast: peak magnitude approx. 0.1 - 0.2 fm/c

Non-zero Δv_1 mainly due to magnetic field from spectators

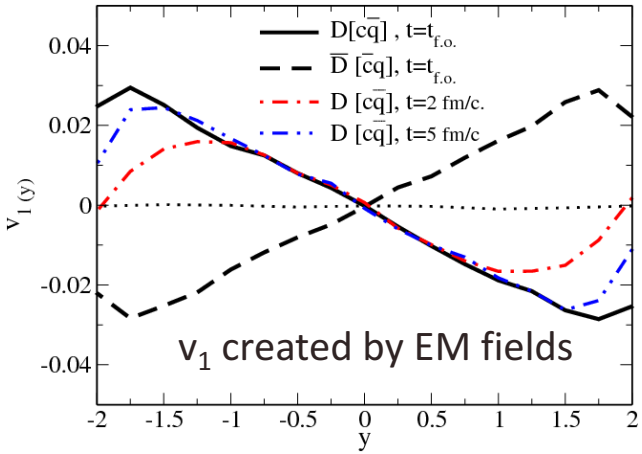


Larger effect on D^0 mesons

$\Delta \equiv (\pi^+ - \pi^-)$

Phys. Rev. C **98**, 055201 (2018)

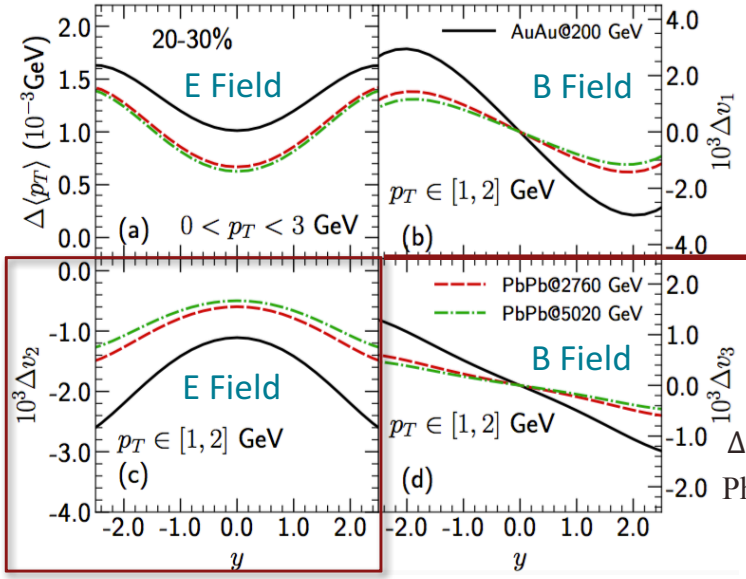
Phys. Lett. B **768**, 260 (2017)



Effect on Δv_2 of D^0 Mesons

Mostly produced by Electric field from collision participants

- Coulomb interaction



Bigger effect on D^0 meson Δv_2?

Δv_2 measured for D^0 mesons!!!

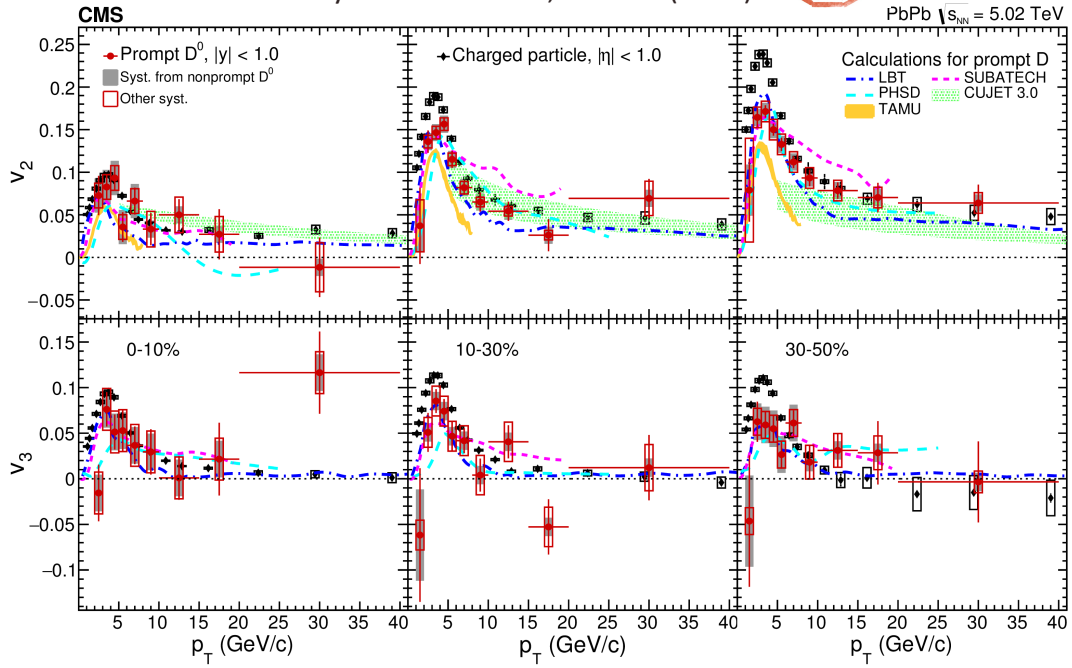
$\Delta \equiv (\pi^+ - \pi^-)$

Phys. Rev. C **98**, 055201 (2018)

Previous Measurements by CMS: 2015 Data

Prompt D^0 v_2 and v_3: comparison with charged hadrons & theory

Phys. Rev. Lett. **120**, 202301 (2018)



v_2 is centrality dependent

v_3 small centrality dependence

v_2 and v_3 similar p_T dependence as charged hadrons

Suggests charm quarks take part of collective motion

Measurements for $|y| < 1$, $1 < p_T < 40$ GeV

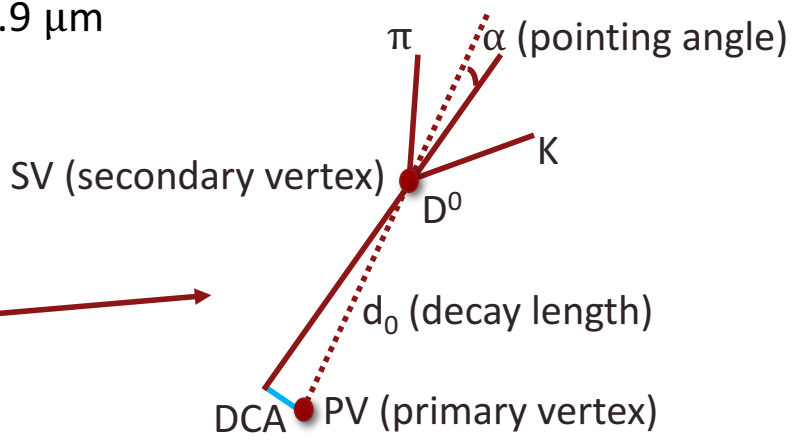
D^0 Reconstruction and Selection: 2018 Data

Minimum Bias events from PbPb collisions at 5.02 TeV

$D^0 \rightarrow K\pi$, BR = 3.88 $\pm$ 0.05 %, $c\tau(D^0)$ = 122.9 μm

D^0 Reconstruction

- Pairing oppositely charged tracks (no PID)
- Secondary vertex reconstruction



Prompt D^0 candidate selection

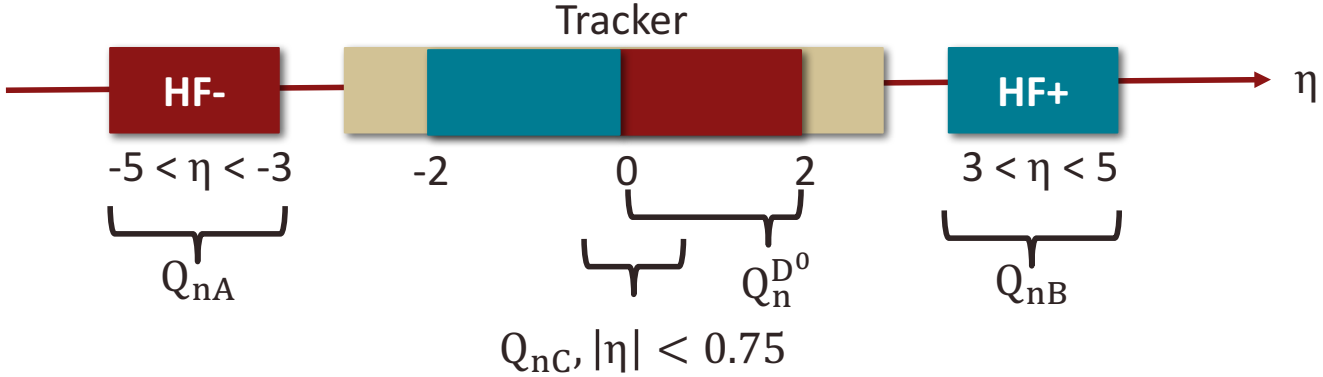
- MVA Boosted Decision Tree (BDT)
  - D^0 variables
    - $d_0/\sigma(d_0)$, α, SV probability
  - Tracks (Kπ)
    - Distance of closest approach significance, error on p_T, number of hits

Nonprompt D^0 (from B hadron decay) contamination (as systematic uncertainty)

- Estimate contribution using DCA variable (nonprompt D^0 enriched region for DCA > 0.012 cm)

Flow Measurement: Scalar Product Method

v_2, v_3, $\Delta v_2(D^0 - \overline{D^0})$ as functions of centrality, rapidity and p_T



- $Q_n = \sum_j w_j e^{in\phi_j}$ (w_j = tower E_T for HF, w_j = track p_T for tracker, w_j = 1 for $D^0, \overline{D^0}$)

- $v_n\{SP\} = \dfrac{\left\langle Q_n^{D^0/\overline{D^0}} Q_{nA}^* \right\rangle}{\sqrt{\dfrac{\langle Q_{nA} Q_{nB}^* \rangle \langle Q_{nA} Q_{nC}^* \rangle}{\langle Q_{nB} Q_{nC}^* \rangle}}}$ $\quad \Delta v_n\{SP\} = \dfrac{\left\langle Q_n^{D^0} Q_{nA}^* \right\rangle - \left\langle Q_n^{\overline{D^0}} Q_{nA}^* \right\rangle}{\sqrt{\dfrac{\langle Q_{nA} Q_{nB}^* \rangle \langle Q_{nA} Q_{nC}^* \rangle}{\langle Q_{nB} Q_{nC}^* \rangle}}}$ Average over all events

Signal Extraction: simultaneous fit on mass

Simultaneous fit on mass distribution and v_n (Δv_n) versus mass

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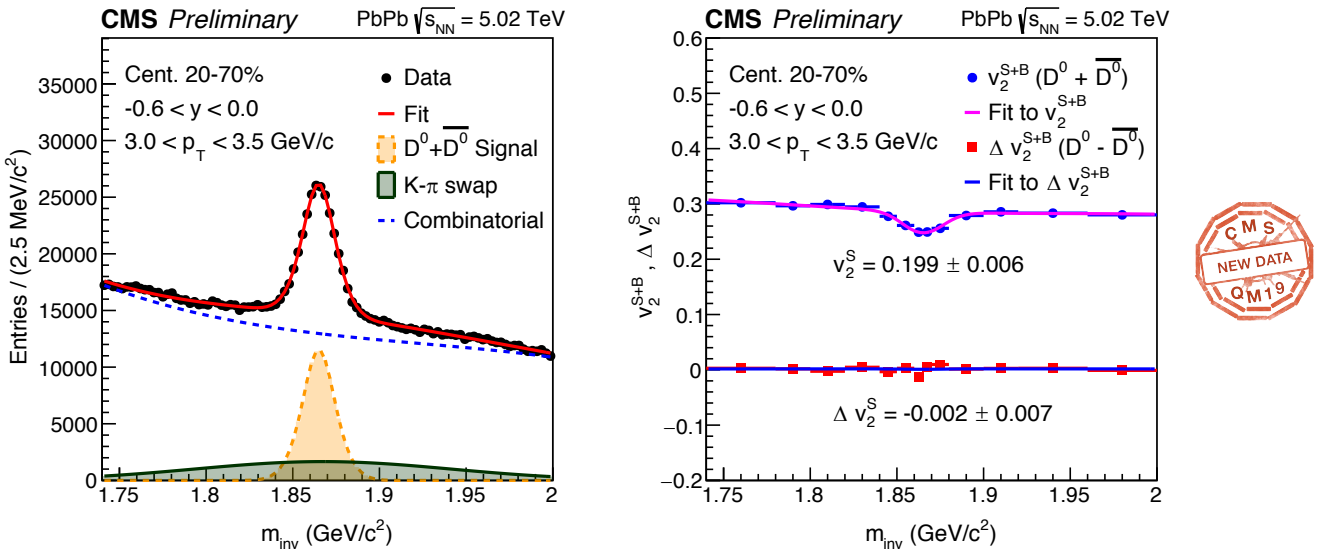


- Mass fit: background (3rd order polynomial), signal (double Gaussian), swap (single Gaussian)
- v_n background (linear function), Δv_n (background is canceled)

Flow Coefficients (v_2 & v_3) as Functions of p_T

Mid-rapidity Region (|y|<1)

Smaller uncertainties compared to 2015 data

- Better constraint on theoretical models

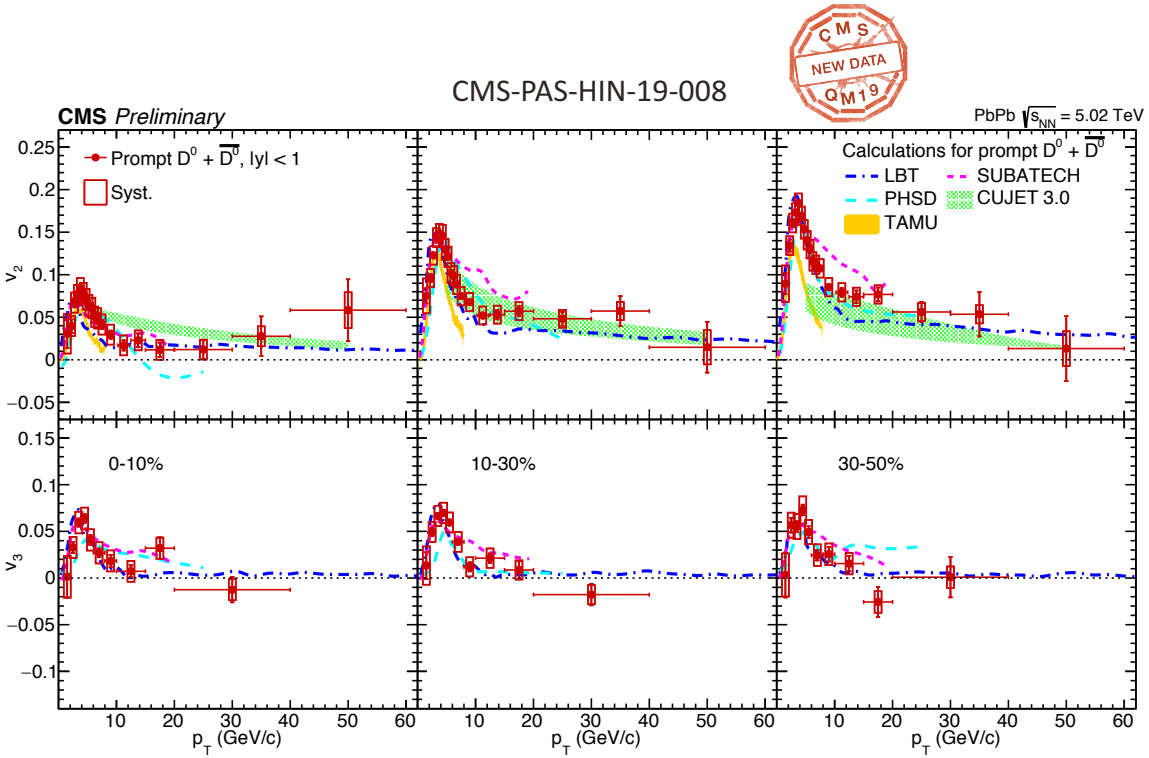
v_2 : considerable dependence on centrality

v_3 : small dependence on centrality

Theory

- Resonable qualitative description
- Further tunning needed for better quantitative description

CMS-PAS-HIN-19-008



LBT [Phys. Rev. C **94**, 014909 (2016)]; PHSD [Phys. Rev. C **89**, 034906 (2014)]; TAMU [Phys. Lett. B **735**, 445 (2014)]; SUBATECH [Phys. Rev. C **91**, 014904 (2015)]; CUJET 3.0 [JHEP **02**, 169 (2016)]

v_2 & v_3 as Functions of p_T (|y|<1 vs 1<|y|<2)

Forward region (1<|y|<2) measured for first time

Overall similar behavior

- Small deviation at high-p_T
- Similar features as in charged hadrons

Important information for 3D hydrodynamic medium description

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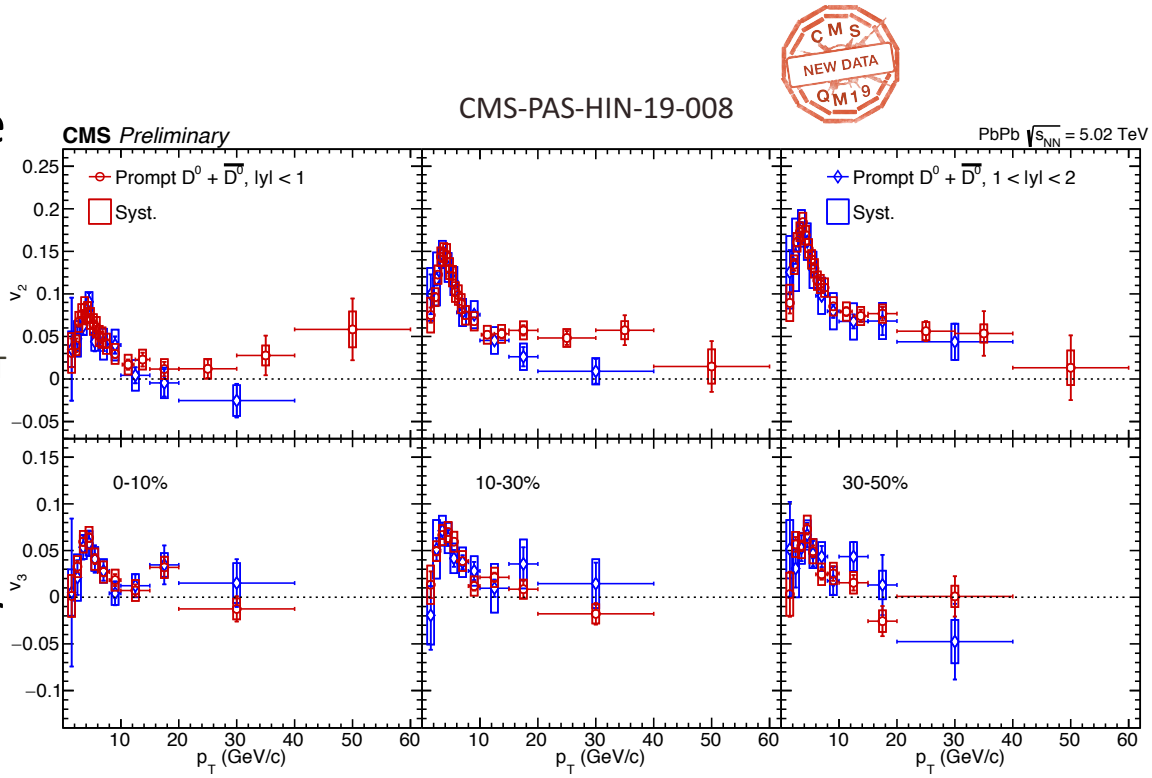

v_2 & v_3 as Function of Centrality

Mid-rapidity & forward region

- Similar trends

Clear dependence of v_2 as function of centrality

v_3 is almost constant with centrality

v_n trends understood in terms of collision geometry

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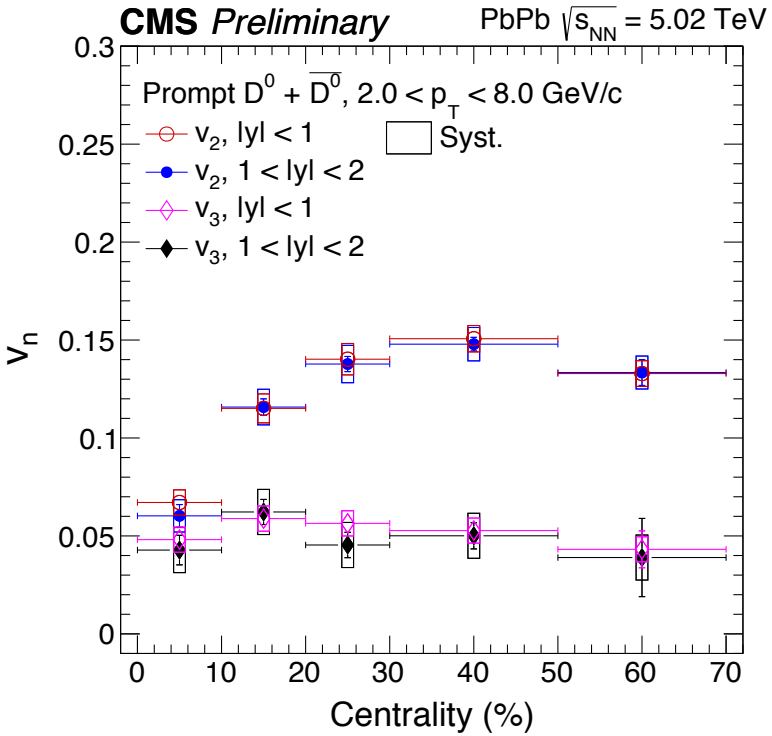

v_2 & v_3 as Function of Rapidity

Weak dependence observed

Slight tendency to lower values at larger rapidities

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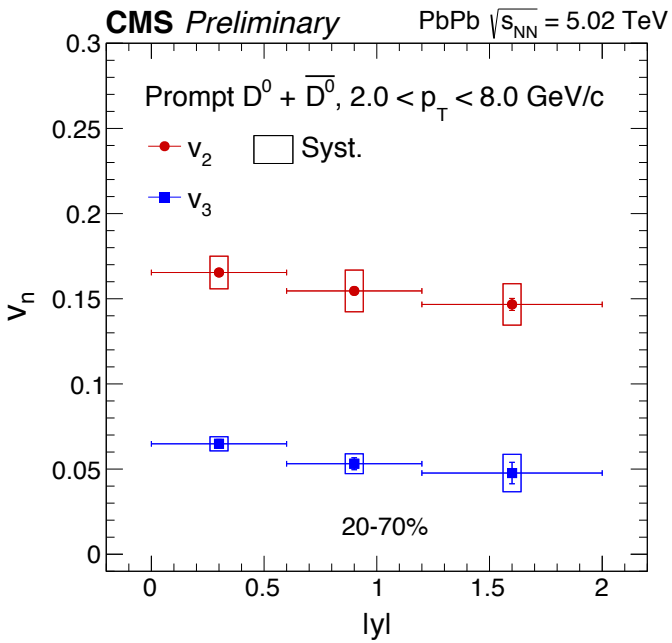

$\Delta v_2(D^0 - \overline{D^0})$ as Function of Rapidity

Electric field can generate non-zero Δv_2

- Currently, no theoretical predictions for D^0
  - Predictions for charged hadrons at LHC energies: $|\Delta v_2| \sim 0.001$ [Phys. Rev. C **98**, 055201 (2018)]
  - Expected bigger values for D^0 [Phys. Rev. C **98**, 055201 (2018)]

Average value extracted with a fit to data

- $\Delta v_2^{\mathrm{Fit}} = 0.001 \pm 0.001\ (\mathrm{stat}) \pm 0.003\ (\mathrm{syst})$

Comparable to the values for charged hadrons

- Constrain medium properties: electric conductivity

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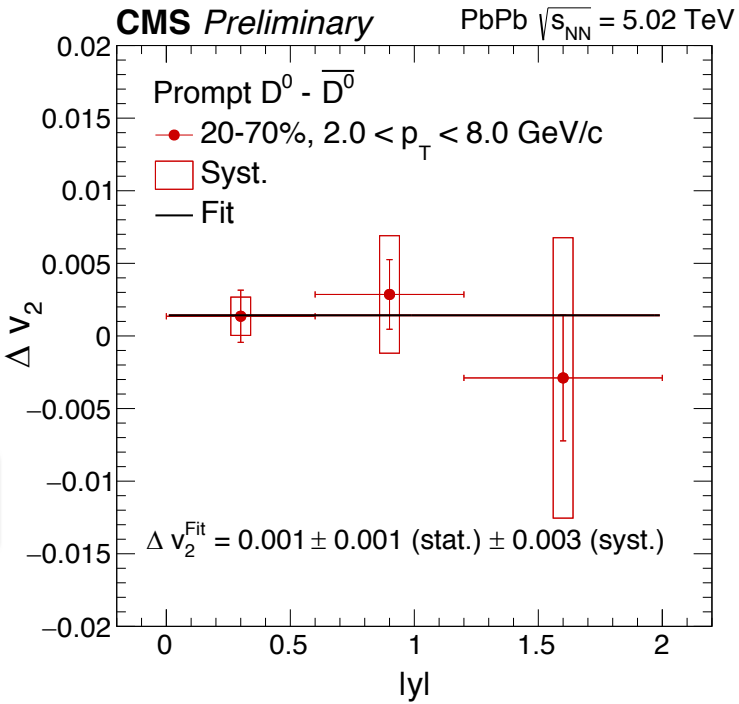

Summary

Search for EM fields in PbPb collisions using CMS detector

- First measurement of $\Delta v_2(D^0 - \overline{D^0})$
- Average: $\Delta v_2^{Fit} = 0.001 \pm 0.001\ (stat) \pm 0.003\ (syst)$
- Information can constrain medium electric conductivity

Flow coefficients: extension of previous measurements by CMS

- Higher p_T coverage and finer bins in both p_T and centrality
- Rapidity dependence of v_2 and v_3
  - $1<|y|<2$ range measured for the first time
- Overall good qualitative theory description of the data
- Similar trends of D^0 flow coefficients as compared to pions

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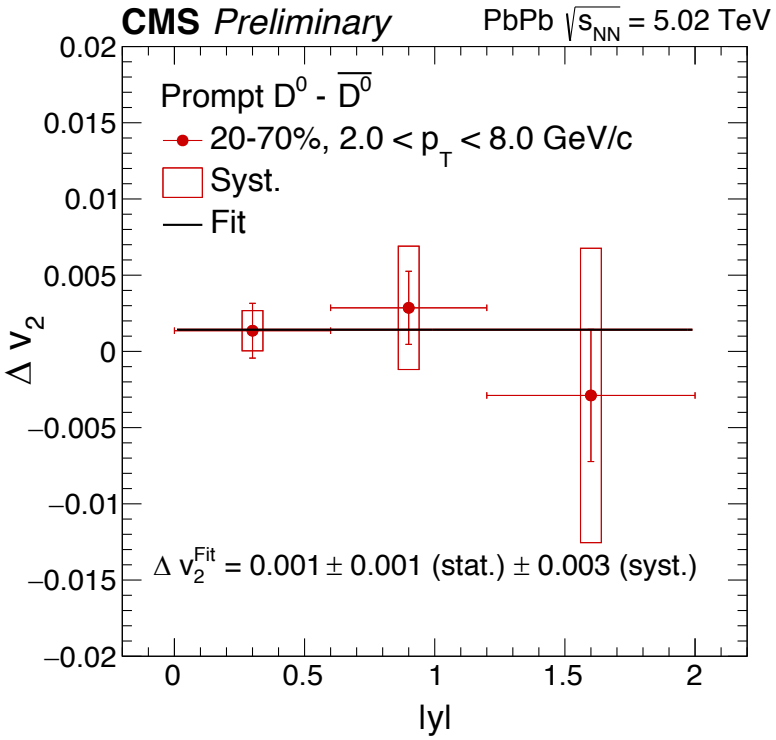

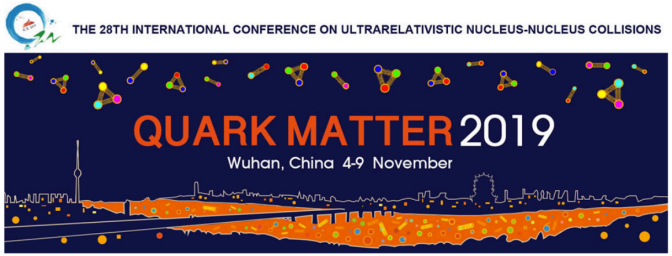

Thank You!!!

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