Quarkonium azimuthal anisotropy at forward rapidity in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with ALICE

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1 – Physics motivations

Charm and beauty created early in collisions: excellent probes of the deconfined medium. Quarkonium states (like $J/\psi$ or $\Upsilon(1S)$) undergo:

- suppression, originally due to color screening with surrounding charges
- regeneration, recombination of thermalized heavy quarks in the medium

Quantify by $R_{AA}$ ($>1$ enhancement, <1 suppression, Pb–Pb w.r.t. pp collisions)

- $T(1S)$ suppressed in Pb–Pb (but large fraction from feed-down) [2]

2 – Azimuthal anisotropy

In non-central heavy-ion collisions, the nuclear overlap region has a spatial anisotropy. During system expansion, pressure gradients generated by parton interactions, transform the spatial anisotropy into a momentum space anisotropy of produced particles [3].

Azimuthal distributions of final state particles can be decomposed by Fourier series (with $n_c$ harmonics):

$$dN/d\phi \propto 1 + 2 \sum_{n=1}^{N_{\text{har}} \leq 4} v_n \cos[n(\phi - \psi_n)]$$

where $\psi$: azimuthal angle, and $\psi_n$: symmetry planes. $v_n$ coefficients: sensitive to initial conditions, equation of state, and medium transport properties.

$v_2$ is called elliptic flow, and $v_3$ triangular flow,...

3 – ALICE experimental setup, muon and dimuon tracks reconstruction

- VOA, V0C, SPD: multiplicity, event flow vector $Q_n = \sum e^{i n \phi}$, vertex
- muon spectrometer: $Q_2$ obtained from $\Upsilon(1S)$ quarkonia via dimuon decay channel (forward rapidity)

4 – Analysis details, signal extraction and $v_n$ measurement

Scalar product (SP) method, three sub-event technique (A,B,C sub-detectors: SPD, VOA, V0C): suppress non-flow effects [4]:

$$v_n(\text{SP}) = \left( \frac{1}{Q_n^2} \sum_{i} q_i Q_i \right)_{\mu \mu} = \left( \frac{1}{Q_n^2} \sum_{i} q_i Q_i \right)_{\mu \mu} = \left( \frac{1}{Q_n^2} \sum_{i} q_i Q_i \right)_{\mu \mu} = \left( \frac{1}{Q_n^2} \sum_{i} q_i Q_i \right)_{\mu \mu}$$

$v_n(\text{SP})$ values are extracted from invariant mass distribution, through $\alpha = S/(S+B)$.

$v_n(\text{SP})$: obtained from dimuon $v_n/m_{\mu\mu}$ fit

$v_n(\mu\mu) = \alpha(\mu\mu) v_n^{\text{deg}} + [1 - \alpha(\mu\mu)] v_n^{\text{deg}}(\mu\mu)$.

5 – Results: $p_T$ and centrality dependence

- Mass hierarchy at low $p_T$ for $\pi$, $D$, and $J/\psi$, while path-length dependent effects dominate at high $p_T$

- Low $p_T$: $v_2/v_0^{\text{deg}}$ increases from unity toward peripheral collisions, while at high $p_T$ it is compatible with 1

6 – Global picture: from light, to charm, to beauty flavor, and summary

- $v_2^{\text{J/\psi}}$ favors scenario that all initially created $J/\psi$ dissociate in the medium, recombination of charm quarks dominates the $J/\psi$ production [5]

- $v_2^{\text{J/\psi}} > 0$ in $0 - 10$, 2 $< p_T < 5$ GeV/$c$ (3.1r), no centrality dependence

- Low $p_T$: $v_2^{\text{J/\psi}}/v_0^{\text{deg}}$ increases from central to peripheral collisions, compatible with the scenario where $c$ quarks thermalize later than the light ones

- $v_2^{(1S)}$: compatible with 0 and model predictions [6-8]

References