Centrality Dependence of Azimuthal Anisotropy of Strange Hadrons in 200 GeV Au+Au Collisions

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Overview

- Motivation
- Analysis details and technique
- Data and results for \( v_2 \) and \( v_4 \)
- Discussion
- Conclusions
Elliptic flow $v_2$

- non-central collisions: azimuthal anisotropy in coordinate-space
- interactions $\Rightarrow$ asymmetry in momentum-space
- sensitive to early time in the system’s evolution

Measurement: Fourier expansion of the azimuthal $p_T$ distribution

$$E \frac{d^3N}{d^3p} = \frac{1}{\pi} d^2 \frac{N}{dp_T^2dy} [1 + 2v_1 \cos(\phi - \Psi_R) + 2v_2(2[\phi - \Psi_R]) + ...]$$

$v_2 = \langle \cos(2[\phi - \Psi_R]) \rangle$
Flow of strange hadrons

- freeze-out of multi-strange hadrons
  - at higher temperature $T_{fo}$
  - with lower collective velocity $\langle \beta_T \rangle$

→ less interaction of strange hadrons with non-strange hadrons

- sensitivity to the early, partonic stage

[Graph showing flow of strange hadrons with temperature $T_{fo}$ and collective velocity $\langle \beta_T \rangle$.]

Dataset and analysis method

- **system**: Au+Au collisions
- **energy**: $\sqrt{s_{NN}} = 200$ GeV

- **event sample**:
  - 13.3 M events 0–80%
  - 6.6 M events 40–80%
  - 5.0 M events 10–40%
  - ~19 M events 0–10%

- **event plane resolution**:
  - 76% for 0–80%
  - 66% for 40–80%
  - 82% for 10–40%
  - 69% for 0–10%

- **analysis method**: $v_2$ vs. $m_{\text{inv}}$
- **motivated by** Borghini *et al.* [nucl-th/0407041]
- **detailed studies regarding systematic uncertainties still underway**
- **for $K^0_S$ and $\Lambda+\bar{\Lambda}$**
  - ~5% error on $v_2$ for $p_T<4$ GeV/$c$
  - rising up to ~25–30% at $4<p_T<6$ GeV/$c$
  - possible significant non-flow contribution for $p_T>5$ GeV/$c$

- **Only statistical errors shown in this presentation!**
Min. bias $v_2(p_T)$ for strange hadrons

- Mass ordering at low $p_T$
- ‘Standard’ Hydro calculation: $T_{ch} = 165$ MeV, $T_{kin} = 130$ MeV
  [P. Huovinen, private communication]
- Model works reasonably well for min. bias at low $p_T$
Centrality dependence of $v_2(p_T)$

- available high statistics allows for measurement of centrality dependence of $v_2(p_T)$
- comparison to Hydro model calculations shows deviations even at low $p_T$

$K^0_S$ and $\Lambda$ data provided by Yan Lu

→ poster on Thursday
NCQ scaling of $v_2(p_T)$ for min. bias

- scaled meson and baryon $v_2$ agrees at intermediate $p_T$
- high statistics measurements show deviation from ideal scaling

PHENIX
Centrality dependence of NCQ scaling

- polynomial fit through $K_S^0$, $\Lambda$, and $\Xi$ data
- NCQ scaling seems to work for different centralities as well

See Yan Lu’s poster on Thursday!
\( v_4 \) for \( \Xi^- \) and \( \Xi^+ \)

- Observation of sizable \( v_4 \) with strong \( p_T \) dependence
- \( v_4 \) scales with \( \sim 1.2 \, v_2^2 \) (as it for charged hadrons)
  

- Ideal fluid dynamics would lead to \( v_4/v_2^2 = 0.5 \)
  
  [Borghini and Ollitrault, nucl-th/0506045; Kolb, Phys. Rev. C 68, 031902(R)]

Will \( v_4/v_2^2 \) be closer to 0.5 at LHC?
Conclusions

- **The strong flow of strange and multi-strange hadrons indicates collectivity among partons!**

- **Strange hadron v$_2$ at low p$_T$:**
  - show mass ordering
  - follow hydro model for minimum bias
  - deviate from hydro model predictions for different centralities

- **NCQ scaling of v$_2$ at intermediate p$_T$:**
  - deviations from ideal NCQ scaling become visible for minimum bias
  - indication for NCQ scaling even for different centralities

- **v$_4$ of Ξ$^{-}$+Ξ$^{+}$:**
  - shows same scaling (1.2 v$_2^2$) as other particle species
  - Hint for incomplete thermalisation?
Analysis technique

- analysis method: $v_2$ vs. $m_{inv}$
- motivated by Borghini et al. [nucl-th/0407041]

$$v_2^{TOT}(m_{inv}) = \langle \cos(2(\phi - \Psi)) \rangle = \frac{v_2^{SIG}(m_{inv})}{SIG + BG} + v_2^{BG}(m_{inv}) \cdot \frac{BG}{SIG + BG}(m_{inv})$$

- advantages over standard method:
  - only one fit per $p_T$ bin
  - smaller systematic uncertainties
- method used for $K^0_S$, $\Lambda$, $\Xi$, $\Omega$,
- **standard method** and $v_2$ vs. $m_{inv}$ method give consistent results and provide means for estimating systematic errors
Systematic error estimations for $K^0_S$ and $\Lambda$