Elliptic and triangular flow of identified particles measured with the ALICE detector.

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Motivation

- Integrated flow larger by 30% than at RHIC.
- Differential flow of charged particles almost same.
- Is this expected in hydrodynamic models?
- Does quark scaling work at the LHC?
- Is triangular flow similar to elliptic flow?
  - Low $p_t$ mass scaling?
  - Quark scaling?
Analysis outline

• Data sample:
  • ~4M Pb-Pb events at $\sqrt{s}=2.76\text{TeV}$,
  • minimum bias trigger,
  • acceptance: $-0.8<\eta<0.8$.

• Detectors used:
  • time-of-flight (particle identification),
  • time projection chamber (tracking & particle id.),
  • inner tracking system (tracking).

• Sources of systematic uncertainty considered:
  • non-flow,
  • feed-down,
  • centrality determination.
Particle identification

- Particle identification tuned for purity>95%:
  - $\pi$ and $K$: $p<3\text{GeV}/c$,  
  - proton: $p<5\text{GeV}/c$.
- PID cuts:
  - asymmetric cut on beta in the time-of-flight detector.
  - Additional $2\sigma$ cut on $dE/dx$ in the time projection chamber to clean the data.
Elliptic flow of identified particles

- Centrality dependence of $v_2$ for pions, kaons and antiprotons.
- Method: scalar product with $|\Delta \eta| > 1$ to reduce non-flow correlations.
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Viscous hydro & data

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- Data and prediction disagree for protons in more central events.
- Hydro prediction better for peripheral events at low $p_t$. 
From RHIC to LHC

- Hydrodynamic models predict a larger mass splitting at low $p_t$, mostly due to shift in proton flow.
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Flow of anti-protons at LHC shows a shift similar to prediction.

- Larger mass splitting.
LHC flow rescaled

Elliptic flow per quark vs transverse kinetic energy per quark ($KE_t$ scaling).

Hydro prediction shows compression;
  - At low $p_t$ better agreement between $\pi$ and $K$.

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M.Krzewicki, ALICE, PID flow
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- Hydro prediction shows compression;
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- Data shows agreement between $\pi$ and K, anti-protons do not follow the scaling.
Triangular flow

- In the Glauber picture triangularity due to fluctuations of initial state.
- Magnitude of (final state) $v_3$ sensitive to $\eta/s$.
- How large is the triangular flow ($v_3$)?
- Does it show hydro-like features like $v_2$?
- $v_3$ in two centrality bins, two-particle method, no eta gap.
- Low pt mass scaling as expected from the hydro picture.
- $v_3$ of pions and protons cross at intermediate $p_t$ as expected from coalescence.
- Magnitude suggests $\eta/s < 0.16$. 

**Triangular flow**

![Graph 1](image1.png)

![Graph 2](image2.png)
Triangular flow rescaled

- $v_3$ per quark vs transverse kinetic energy per quark.
- mid-central: at low $p_t$ no scaling.
- mid-peripheral: scaling different than for $v_2$. 
Summary

• We have shown the elliptic flow of identified particles at LHC:
  • Hydrodynamics describes peripheral events quite well.
  • In more central events hydro and data disagree.
  • Results consistent with larger mass splitting compared to RHIC.
  • $K_{E_t}$ scaling for $v_2$ seems worse than at RHIC.

• Triangular flow of identified particles at LHC:
  • Mass scaling as expected based on hydro.
  • Crossing point as expected based on coalescence.
  • Indication of $\eta/s<0.16$.
  • $K_{E_t}$ scaling qualitatively differs from scaling of $v_2$. 
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