Anomalous evolution of the near-side jet peak shape in Pb-Pb collisions with ALICE

Monika Kofarago
MTA Wigner RCP

on behalf of the ALICE Collaboration

31st March 2017 – Moriond QCD

arXiv:1609.06643
arXiv:1609.06667
Physics motivation

Goal: study interaction of jets with medium

Angular correlation measurements
- Analysis done on a statistical basis
- Subtraction of large fluctuating background possible
- Low $p_T$ measurement possible
- Complementary tool to jet reconstruction

ALICE event display with jet
Physics motivation

- **Goal**: study interaction of jets with medium
- **Angular correlation measurements**
  - Analysis done on a statistical basis
  - Subtraction of large fluctuating background possible
  - Low $p_T$ measurement possible
  - Complementary tool to jet reconstruction
- Interactions would appear as modification of the near-side peak
- Modification of the jet-peak has been seen by STAR

Theoretical aspects

- Larger width in $\Delta \eta$ than in $\Delta \phi$
  - Interaction with longitudinal flowing medium
    Armesto, Salgado, Wiedemann, PRL 93,242301 (2004)

- Interaction with turbulent color fields

- Double hump-shape in the energy distribution of the jet
Analysis strategy

- Pb–Pb and pp data at $\sqrt{s_{NN}} = 2.76$ TeV
- Trigger and associated particle taken in certain $p_T$ window
- Associated yield per trigger:

$$\left(1 / N_{\text{trig}}\right) \frac{d^2 N_{\text{assoc}}}{d\Delta\eta d\Delta\varphi}$$
Evolution of the near-side peak shape

- Histograms background subtracted for illustration
- Shape is similar in pp and peripheral collisions
Evolution of the near-side peak shape

- Histograms background subtracted for illustration
- Peak: broader and asymmetric in central collisions
Evolution of the near-side peak shape

- Histograms background subtracted for illustration
- Depletion around \((\Delta \varphi, \Delta \eta) = (0,0)\) in central collisions at low \(p_T\)
Evolution of the near-side peak shape

- Histograms background subtracted for illustration
- Peak is narrower at high $p_T$

ALICE, $\sqrt{s} = 2.76$ TeV

$1 < p_{T,\text{trig}} < 2$ GeV/c
$1 < p_{T,\text{assoc}} < 2$ GeV/c

$3 < p_{T,\text{trig}} < 4$ GeV/c
$2 < p_{T,\text{assoc}} < 3$ GeV/c

ALICE, pp

ALICE, Pb-Pb

$\sqrt{s_{NN}} = 2.76$ TeV

50-80%

0-10%
Fitting technique

- The near-side is fitted to characterize its shape evolution
- Fit function: background + Generalized Gaussian
  - Background:
    \[ C_1 + \sum_{n=2}^{4} 2V_n \cos(n\Delta \varphi) \]
  - Generalized Gaussian:
    \[ N \times e^{-\left| \frac{d\varphi}{w_{\varphi}} \right|^\gamma_{\varphi} - \left| \frac{d\eta}{w_{\eta}} \right|^\gamma_{\eta}} \]
    \[ \Rightarrow N = C_2 \times \frac{\gamma_{\varphi} \gamma_{\eta}}{4w_{\varphi}w_{\eta}\Gamma\left(\frac{1}{\gamma_{\varphi}}\right)\Gamma\left(\frac{1}{\gamma_{\eta}}\right)} \]
    \[ \gamma = 1: \text{Exponential} \]
    \[ \gamma = 2: \text{Gaussian} \]

- Characterize peak by variance of generalized Gaussian:
  \[ \sigma^2 = \frac{w^2\Gamma(3/\gamma)}{\Gamma(1/\gamma)} \]

- No attempt to give physical meaning to parameters of the generalized Gaussian
- Some bins around \((\Delta \varphi, \Delta \eta) = (0,0)\) are excluded from the fit
Fitting illustration

ALICE, Pb-Pb
\( \sqrt{s_{NN}} = 2.76 \text{ TeV} \)

0-10%

Background

Peak

\( 3 < p_{T,\text{trig}} < 4 \text{ GeV/c} \)
\( 2 < p_{T,\text{assoc}} < 3 \text{ GeV/c} \)

\( \frac{1}{N_{\text{sig}}} \frac{d^2 N_{\text{assoc}}}{d\eta d\phi} \) (rad)

\( \frac{1}{N_{\text{sig}}} \frac{d^2 N_{\text{assoc}}}{d\eta d\phi} \) (rad)

\( \frac{1}{N_{\text{sig}}} \frac{d^2 N_{\text{assoc}}}{d\eta d\phi} \) (rad)

Data
Fit
Background

\( = 2.76 \text{ TeV} \)

ALICE, Pb-Pb

\( c < 4 \text{ GeV/T, trig} \)
\( p_3 < c < 3 \text{ GeV/T, assoc} \)
\( p_2 < | < 1.6 \eta_{\Delta} | < 4\% \) scale uncertainty

Monika Kofarago
Anomalous evolution of the near-side jet peak shape in Pb-Pb collisions with ALICE
Small signal over background ratio

Fit describes the data very well
Characterize peak by the variance of the fit: $\sigma^2 = \frac{w^2 \Gamma(3/\gamma)}{\Gamma(1/\gamma)}$.
Width of the near-side peak

- Characterize peak by the variance of the fit: $\sigma^2 = \frac{w^2 \Gamma(3/\gamma)}{\Gamma(1/\gamma)}$

- Ordering of the width according to $p_T$

- Width in $\Delta \varphi$ in 50–80% is equal to width in pp
Width of the near-side peak

- Characterize peak by the variance of the fit: \( \sigma^2 = \frac{w^2 \Gamma(3/\gamma)}{\Gamma(1/\gamma)} \)

- Ordering of the width according to \( p_T \)
- Width in \( \Delta \varphi \) in 50–80% is equal to width in pp
- Small increase at low \( p_T \) in \( \Delta \varphi \) with centrality
Width of the near-side peak

- Characterize peak by the variance of the fit: \( \sigma^2 = \frac{w^2 \Gamma(3/\gamma)}{\Gamma(1/\gamma)} \)

- Ordering of the width according to \( p_T \)

---

\( \sigma_{\Delta \phi} \) (rad) or \( \sigma_{\Delta \eta} \)

- Centrality (%)
- \( 0 \) 20 40 60 80 pp
- \( \eta \Delta \sigma \) (rad) or \( \phi \Delta \sigma \)
- \( 0 \) 0.2 0.4 0.6 0.8 1

ALICE

Pb-Pb \( \sqrt{s_{NN}} = 2.76 \text{ TeV} \)

pp \( \sqrt{s} = 2.76 \text{ TeV} \)

**ALI-PUB-112807**

Monika Kofarago

Anomalous evolution of the near-side jet peak shape in Pb-Pb collisions with ALICE
Width of the near-side peak

Characterize peak by the variance of the fit: \( \sigma^2 = \frac{w^2 \Gamma(3/\gamma)}{\Gamma(1/\gamma)} \)

- Ordering of the width according to \( p_T \)
- Width in \( \Delta\eta \) in 50–80% is already larger than in pp
Width of the near-side peak

- Characterize peak by the variance of the fit: \( \sigma^2 = \frac{w^2 \Gamma(3/\gamma)}{\Gamma(1/\gamma)} \)

- Ordering of the width according to \( p_T \)
- Width in \( \Delta\eta \) in 50–80% is already larger than in pp
- Very pronounced increase at low \( p_T \) in \( \Delta\eta \)
Comparison to models

- Study if interplay of flow and jets could cause the observed effects
- **AMPT (A Multi-Phase Transport model)** [1]
  - Addresses non-equilibrium many-body dynamics
  - Has collective effects through partonic and hadronic interactions
  - Large longitudinal flow in AMPT $\Rightarrow$ longitudinal broadening [2]
  - Different settings available to study the origin and the effect of flow

AMPT

**Settings:**
- string melting off, hadronic rescattering on
- string melting on, hadronic rescattering on
- string melting on, hadronic rescattering off

![Diagram showing stages of AMPT](image)
**Settings:**
- string melting off, hadronic rescattering on
- string melting on, hadronic rescattering on
- string melting on, hadronic rescattering off
Settings:
- string melting off, hadronic rescattering on
- string melting on, hadronic rescattering on
- string melting on, hadronic rescattering off

Initial stage

From HIJING excited strings and minijet partons

String melting on

Strings fragment into partons

Partonic rescattering (ZPC)

Quark coalescence

Hadronic rescattering (ART)
Settings:
- string melting off, hadronic rescattering on
- string melting on, hadronic rescattering on
- string melting on, hadronic rescattering off

From HIJING
excited strings and minijet partons

String melting on

Strings fragment into partons

Partonic rescattering (ZPC)

Quark coalescence

Hadronic rescattering (ART)
Quantification of the broadening

- Ratio of width in central over peripheral:

\[
\sigma_{CP}^{\Delta \varphi} = \frac{\sigma_{\Delta \varphi}(0-10\%) - \sigma_{\Delta \varphi}(50-80\%)}, \quad \sigma_{CP}^{\Delta \eta} = \frac{\sigma_{\Delta \eta}(0-10\%) - \sigma_{\Delta \eta}(50-80\%)}
\]

- Moderate broadening in \( \Delta \varphi \)

\[
\Delta \varphi
\]

\[
\sigma_{CP}^{\Delta \varphi}
\]

\[
p_{T,\text{trig}} \text{(GeV/c)}
\]

\[
p_{T,\text{assoc}} \text{(GeV/c)}
\]

\[
ALICE \quad \text{Pb-Pb } \sqrt{s_{NN}} = 2.76 \text{ TeV}
\]

Monika Kofarago
Anomalous evolution of the near-side jet peak shape in Pb-Pb collisions with ALICE
Quantification of the broadening

- Ratio of width in central over peripheral:

\[
\sigma_{\Delta \varphi}^{CP} = \frac{\sigma_{\Delta \varphi}(0-10\%)}{\sigma_{\Delta \varphi}(50-80\%)} \quad \sigma_{\Delta \eta}^{CP} = \frac{\sigma_{\Delta \eta}(0-10\%)}{\sigma_{\Delta \eta}(50-80\%)}
\]

- Moderate broadening in \( \Delta \varphi \)
- Much larger broadening in \( \Delta \eta \)

<table>
<thead>
<tr>
<th>ALICE</th>
<th>Pb-Pb ( \sqrt{s_{NN}} = 2.76 \text{ TeV} )</th>
<th>( \sigma_{\Delta \varphi}^{CP} )</th>
<th>( \sigma_{\Delta \eta}^{CP} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Monika Kofarago
Anomalous evolution of the near-side jet peak shape in Pb-Pb collisions with ALICE
Quantification of the broadening

- Ratio of width in central over peripheral:

\[ \sigma_{\Delta \varphi}^{CP} = \frac{\sigma_{\Delta \varphi}(0-10\%)}{\sigma_{\Delta \varphi}(50-80\%)}, \quad \sigma_{\Delta \eta}^{CP} = \frac{\sigma_{\Delta \eta}(0-10\%)}{\sigma_{\Delta \eta}(50-80\%)} \]

- Moderate broadening in \( \Delta \varphi \)
- Much larger broadening in \( \Delta \eta \)
- Broadening most significant at intermediate \( p_T \)
Quantification of the broadening ratio of width in central over peripheral:

\[ \sigma_{\Delta \varphi}^{CP} = \frac{\sigma_{\Delta \varphi}(0-10\%)}{\sigma_{\Delta \varphi}(50-80\%)} \]

\[ \sigma_{\Delta \eta}^{CP} = \frac{\sigma_{\Delta \eta}(0-10\%)}{\sigma_{\Delta \eta}(50-80\%)} \]

Data

String melting, hadronic rescattering

String melting, hadronic rescattering

\[ \sigma_{\Delta \varphi}^{CP} = \frac{\sigma_{\Delta \varphi}(0-10\%)}{\sigma_{\Delta \varphi}(50-80\%)} \]

\[ \sigma_{\Delta \eta}^{CP} = \frac{\sigma_{\Delta \eta}(0-10\%)}{\sigma_{\Delta \eta}(50-80\%)} \]
Quantification of the broadening ratio of width in central over peripheral:

\[ \sigma_{\Delta \varphi}^{CP} = \frac{\sigma_{\Delta \varphi}(0-10\%)}{\sigma_{\Delta \varphi}(50-80\%)}, \quad \sigma_{\Delta \eta}^{CP} = \frac{\sigma_{\Delta \eta}(0-10\%)}{\sigma_{\Delta \eta}(50-80\%)} \]
Quantification of the broadening

- Ratio of width in central over peripheral:
  \[ \sigma_{CP}^{\Delta \varphi} = \frac{\sigma_{\Delta \varphi}(0-10\%)}{\sigma_{\Delta \varphi}(50-80\%)}, \quad \sigma_{CP}^{\Delta \eta} = \frac{\sigma_{\Delta \eta}(0-10\%)}{\sigma_{\Delta \eta}(50-80\%)} \]

**Data**
- String melting, hadronic rescattering
- String melting off, hadronic rescattering
- Small difference between models in \( \Delta \varphi, \Delta \eta \) more constraining
- String melting off, hadr. rescattering on describes data best

\[ \text{ALICE} \quad \circ \quad \text{Pb-Pb } \sqrt{s_{NN}} = 2.76 \text{ TeV} \]
\[ \text{AMPT} \]
- String melting on, rescattering on
- String melting on, rescattering off
- String melting off, rescattering on

\[ \text{AMPT} \quad \circ \quad \text{Pb-Pb } \sqrt{s_{NN}} = 2.76 \text{ TeV} \]
Quantification of the broadening

- Ratio of width in central over peripheral:

\[
\sigma_{\Delta \varphi}^{CP} = \frac{\sigma_{\Delta \varphi}(0-10\%)}{\sigma_{\Delta \varphi}(50-80\%)}, \quad \sigma_{\Delta \eta}^{CP} = \frac{\sigma_{\Delta \eta}(0-10\%)}{\sigma_{\Delta \eta}(50-80\%)}
\]

- Small difference between models in \(\Delta \varphi\), \(\Delta \eta\) more constraining

- String melting off, hadr. rescattering on describes data best

- Note: none of AMPT settings describe absolute width better than 10% (see backup)
Near-side depletion

- In central collisions at low $p_T$: depletion around $\left(\Delta \varphi, \Delta \eta\right) = (0,0)$
- Per trigger yield is corrected for two-track inefficiencies
- The area of the depletion is excluded from the fit
Near-side depletion

- In central collisions at low $p_T$: depletion around $(\Delta \varphi, \Delta \eta) = (0, 0)$
- Per trigger yield is corrected for two-track inefficiencies
- The area of the depletion is excluded from the fit
- Characterized by $\frac{\text{Fit-Data}}{\text{Total yield}}$ in %

<table>
<thead>
<tr>
<th>$\Delta \eta$</th>
<th>$\text{Fit-Data}$ in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-1$</td>
<td>0</td>
</tr>
<tr>
<td>$0$</td>
<td>0</td>
</tr>
<tr>
<td>$1$</td>
<td>0</td>
</tr>
</tbody>
</table>

![Graph showing data and fit for ALICE, Pb-Pb collisions with $\sqrt{s_{NN}} = 2.76$ TeV.]

- ALICE, Pb-Pb $0-10\%$
- $1 < p_{T,\text{trig}} < 2$ GeV/c
- $1 < p_{T,\text{assoc}} < 2$ GeV/c
- $|\Delta \varphi| < \pi/2$
- 4% scale uncertainty

- Data
- Peak from fit
Near-side depletion

Depletion yield = \( \frac{\text{Fit} - \text{Data}}{\text{Total yield}} \) in %

- No depletion in higher \( p_T \), peripheral or pp

ALICE

\( \sqrt{s_{NN}} = 2.76 \text{ TeV} \)

\[ 1 < p_{T,\text{trig}} < 2 : 1 < p_{T,\text{assoc}} < 2 \text{ GeV/c} \]

\[ 2 < p_{T,\text{trig}} < 3 : 1 < p_{T,\text{assoc}} < 2 \text{ GeV/c} \]

\[ 2 < p_{T,\text{assoc}} < 3 \text{ GeV/c} \]
Near-side depletion in AMPT

String melting on

AMPT
String melting: on
|Δφ| < π/2
Rescattering: on
|Δη| < 1.6

1/N_{trig} \frac{dN_{assoc}}{dΔφ}

Δφ proj.
Δη proj.
Δφ fit
Δη fit

Generator level

String melting off

AMPT
String melting: off
|Δφ| < π/2
Rescattering: on
|Δη| < 1.6

1/N_{trig} \frac{dN_{assoc}}{dΔφ}

Δφ proj.
Δη proj.
Δφ fit
Δη fit

Hadronic rescattering on

Hadronic rescattering off

Monika Kofarago

Anomalous evolution of the near-side jet peak shape in Pb-Pb collisions with ALICE
Near-side depletion in AMPT

**Hadronic rescattering on**

**String melting on**

![Graph showing depletion in AMPT with hadronic rescattering on and string melting on.](image)

**String melting off**

![Graph showing depletion in AMPT with hadronic rescattering on and string melting off.](image)

**Hadronic rescattering off**

**Generator level**

**AMPT with hadronic rescattering on shows depletion independent of string melting**

Monika Kofarago  
Anomalous evolution of the near-side jet peak shape in Pb-Pb collisions with ALICE  
14 / 18
Depletion yield in AMPT almost independent of string melting
AMPT is in agreement with the data at the lowest $p_T$
At higher $p_T$ none of the AMPT versions show depletion
### Summary of the comparison to AMPT

<table>
<thead>
<tr>
<th>AMPT settings Measurements</th>
<th>String melting &amp; hadronic rescattering</th>
<th>String melting</th>
<th>Hadronic rescattering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolution of width</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Absolute width</td>
<td>10%</td>
<td>10 – 15%</td>
<td>20 – 30%</td>
</tr>
<tr>
<td>Depletion</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- With hadronic rescattering describes depletion and shape evolution
- Absolute width is not described better than 10%
Comparison to AMPT – explanation

- Are observed effects described by elliptic and/or radial flow?
- 0–10% fitted with Blast-wave fit to extract expansion velocity ($\beta_T$)
  ($\pi$: $0.5 < p_T < 1$ GeV/c, K: $0.2 < p_T < 1.5$ GeV/c, p: $0.3 < p_T < 2.0$ GeV/c)
- $v_2\{2\}$ was extracted with $0.2 < p_T < 5$ GeV/c
Comparison to AMPT – explanation

- Are observed effects described by elliptic and/or radial flow?
- 0–10% fitted with Blast-wave fit to extract expansion velocity ($\beta_T$)
  ($\pi$: $0.5 < p_T < 1$ GeV/$c$, K: $0.2 < p_T < 1.5$ GeV/$c$, p: $0.3 < p_T < 2.0$ GeV/$c$)
- $v_2\{2\}$ was extracted with $0.2 < p_T < 5$ GeV/$c$

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\beta_T$</th>
<th>$v_2{2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPT string melting and hadronic rescattering</td>
<td>0.442</td>
<td>$0.0412 \pm 0.0002$</td>
</tr>
<tr>
<td>AMPT string melting</td>
<td>0.202</td>
<td>$0.0389 \pm 0.0002$</td>
</tr>
<tr>
<td>AMPT hadronic rescattering</td>
<td>0.540</td>
<td>$0.0330 \pm 0.0002$</td>
</tr>
<tr>
<td>Data*</td>
<td>0.649 $\pm$ 0.022</td>
<td>$0.0364 \pm 0.0003$</td>
</tr>
</tbody>
</table>


- With string melting or with hadr. rescattering describes $v_2\{2\}$
- $\beta_T$ is lower for all AMPT cases than for data
Comparison to AMPT – explanation

- Are observed effects described by elliptic and/or radial flow?
- 0–10% fitted with Blast-wave fit to extract expansion velocity ($\beta_T$)
  ($\pi$: $0.5 < p_T < 1$ GeV/c, K: $0.2 < p_T < 1.5$ GeV/c, p: $0.3 < p_T < 2.0$ GeV/c)
- $v_2\{2\}$ was extracted with $0.2 < p_T < 5$ GeV/c

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\beta_T$</th>
<th>$v_2{2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPT string melting and hadronic rescattering</td>
<td>0.442</td>
<td>0.0412 ± 0.0002</td>
</tr>
<tr>
<td>AMPT string melting</td>
<td>0.202</td>
<td>0.0389 ± 0.0002</td>
</tr>
<tr>
<td>AMPT hadronic rescattering</td>
<td>0.540</td>
<td>0.0330 ± 0.0002</td>
</tr>
<tr>
<td>Data*</td>
<td>0.649 ± 0.022</td>
<td>0.0364 ± 0.0003</td>
</tr>
</tbody>
</table>


**Closest $v_2\{2\}$ to data**

- Only version with hadronic rescattering
  - has depletion
  - follows the centrality and $p_T$ evolution of relative width
Comparison to AMPT – explanation

- Are observed effects described by elliptic and/or radial flow?
- 0–10% fitted with Blast-wave fit to extract expansion velocity ($\beta_T$) ($\pi$: $0.5 < p_T < 1$ GeV/c, K: $0.2 < p_T < 1.5$ GeV/c, p: $0.3 < p_T < 2.0$ GeV/c)
- $v_2\{2\}$ was extracted with $0.2 < p_T < 5$ GeV/c

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\beta_T$</th>
<th>$v_2{2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPT string melting and hadronic rescattering</td>
<td>0.442</td>
<td>0.0412 ± 0.0002</td>
</tr>
<tr>
<td>AMPT string melting</td>
<td>0.202</td>
<td>0.0389 ± 0.0002</td>
</tr>
<tr>
<td>AMPT hadronic rescattering</td>
<td>0.540</td>
<td>0.0330 ± 0.0002</td>
</tr>
<tr>
<td>Data*</td>
<td>0.649 ± 0.022</td>
<td>0.0364 ± 0.0003</td>
</tr>
</tbody>
</table>


**Closest $\beta_T$ to data**

- Has depletion
- Follows the centrality and $p_T$ evolution of relative width
Comparison to AMPT – explanation

- Are observed effects described by elliptic and/or radial flow?
- 0–10% fitted with Blast-wave fit to extract expansion velocity ($\beta_T$)
  ($\pi$: $0.5 < p_T < 1$ GeV/$c$, K: $0.2 < p_T < 1.5$ GeV/$c$, p: $0.3 < p_T < 2.0$ GeV/$c$)
- $v_2\{2\}$ was extracted with $0.2 < p_T < 5$ GeV/$c$

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\beta_T$</th>
<th>$v_2{2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPT string melting and hadronic rescattering</td>
<td>0.442</td>
<td>0.0412 ± 0.0002</td>
</tr>
<tr>
<td>AMPT string melting</td>
<td>0.202</td>
<td>0.0389 ± 0.0002</td>
</tr>
<tr>
<td>AMPT hadronic rescattering</td>
<td>0.540</td>
<td>0.0330 ± 0.0002</td>
</tr>
<tr>
<td>Data*</td>
<td>0.649 ± 0.022</td>
<td>0.0364 ± 0.0003</td>
</tr>
</tbody>
</table>


↓

- Large $\beta_T$ is needed to describe depletion and evolution
- Likely cause of the effects is radial flow
Evolution of near-side peak shape towards low $p_T$ and high centrality:
- Small broadening in $\Delta \varphi$
- Significant broadening in $\Delta \eta$
- Depletion around $(\Delta \varphi, \Delta \eta) = (0,0)$

Comparison to AMPT:
- None of the AMPT settings describe the absolute width
- With only hadronic rescattering describes the evolution of the peak
- With hadr. rescattering describes depletion, independent of string melting

Interpretation:
- Strong longitudinal flow $\Rightarrow$ longitudinal broadening
- Driving factor for depletion and broadening is radial flow
- Depletion and broadening caused by interplay of jets and collective medium

Thank you for your attention!
BACKUP
Further details of the analysis

- 39 million Pb–Pb events at $\sqrt{s_{NN}} = 2.76$ TeV
- 30 million pp events at $\sqrt{s} = 2.76$ TeV
- $|\eta| < 0.8$
- $|z_{vtx}| < 7$ cm
- Selection criteria on decay products: pair excluded if $m_{\text{inv}} < 4$ MeV/$c^2$, $|m_{\text{inv}} - m(\Lambda)| < 5$ MeV/$c^2$ or $|m_{\text{inv}} - m(K^0_S)| < 5$ MeV/$c^2$
- Selection criteria to remove two-track inefficiencies: $|\Delta \eta| > 0.02$ and $|\Delta \varphi^*| > 0.02$ rad
- Correction is done to remove distortion arising from a dependence on $\eta$
Correction with mixed event

- Associated yield per trigger particle:

\[
\frac{1}{N_{\text{trig}}} \frac{d^2N_{\text{assoc}}}{d\Delta\eta d\Delta\varphi} = \frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)}
\]
## Systematic Uncertainties

<table>
<thead>
<tr>
<th>Source</th>
<th>$\sigma_{\Delta \varphi}$</th>
<th>$\sigma_{\Delta \eta}$</th>
<th>$\sigma_{C P, \Delta \varphi}$</th>
<th>$\sigma_{C P, \Delta \eta}$</th>
<th>Depletion yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track selection and efficiencies</td>
<td>1.0%</td>
<td>1.3%</td>
<td></td>
<td></td>
<td>20%</td>
</tr>
<tr>
<td>Small opening angles cut</td>
<td>0.7%</td>
<td>1.3%</td>
<td></td>
<td></td>
<td>5–10%</td>
</tr>
<tr>
<td>Neutral-particle decay cut</td>
<td>0.1%</td>
<td>0.2%</td>
<td></td>
<td></td>
<td>8–20%</td>
</tr>
<tr>
<td>Vertex range</td>
<td>1.0%</td>
<td>1.0%</td>
<td></td>
<td></td>
<td>5–10%</td>
</tr>
<tr>
<td>Pseudorapidity dependence</td>
<td>1.7% 4.1%</td>
<td>0.6% 2.5%</td>
<td></td>
<td></td>
<td>5–15%</td>
</tr>
<tr>
<td>Exclusion region</td>
<td>0.1% 1.0%</td>
<td>0.1% 1.5%</td>
<td></td>
<td></td>
<td>7–28%</td>
</tr>
<tr>
<td>Total</td>
<td>2.3% 4.5%</td>
<td>2.2% 3.6%</td>
<td></td>
<td></td>
<td>24–45%</td>
</tr>
</tbody>
</table>

- Ranges indicate centrality dependence
AMPT settings

- With string melting and with hadronic rescattering
  - Version v2.25t3
  - Parameter isoft = 4
  - Parameter ntmax = 150

- With string melting and without hadronic rescattering
  - Version v2.25t3
  - Parameter isoft = 4
  - Parameter ntmax = 3

- Without string melting and with hadronic rescattering
  - Version v1.25t3
  - Parameter isoft = 1
  - Parameter ntmax = 150
Comparison to the STAR experiment

\[ \sigma_{\Delta \eta} \] vs. \( p_{T,\text{asso}} \) (GeV/c) for ALICE, Pb-Pb, \( \sqrt{s_{NN}} = 2.76 \) TeV

- 0-10%
- 50-80%

\[ \Delta \varphi \] vs. \( p_{T,\text{asso}} \) (GeV/c) for STAR, Au-Au, \( \sqrt{s_{NN}} = 0.2 \) TeV

- 0-12%
- 40-80%

**STAR:** \( \sqrt{s_{NN}} = 200 \) GeV, Au–Au collisions

Taken from Phys.Rev. C85 (2012) 014903

**ALICE:** \( \sqrt{s_{NN}} = 2.76 \) TeV, Pb–Pb collisions

Results agree within 2\( \sigma \) in all bins

Values slightly higher at STAR in the central bins in \( \Delta \varphi \)
Comparison to MC – absolute width in peripheral

- Absolute width described by \( \frac{\sigma_{\Delta \varphi}^{\text{Data}}}{\sigma_{\Delta \varphi}^{\text{MC}}} \), \( \frac{\sigma_{\Delta \eta}^{\text{Data}}}{\sigma_{\Delta \eta}^{\text{MC}}} \)

None of the AMPT settings describe all \( p_T \) bins
Comparison to MC – absolute width in central

- Absolute width described by $\frac{\sigma_{\Delta \varphi}^{\text{Data}}}{\sigma_{\Delta \varphi}^{\text{MC}}}$, $\frac{\sigma_{\Delta \eta}^{\text{Data}}}{\sigma_{\Delta \eta}^{\text{MC}}}$

\begin{align*}
\text{ALICE} & \quad \text{Pb-Pb } \sqrt{s_{NN}} = 2.76 \text{ TeV} \\
\text{AMPT, string melting on, rescattering on} & \quad 0-10\% \\
\text{AMPT, string melting on, rescattering off} & \quad pp \sqrt{s} = 2.76 \text{ TeV} \\
\text{AMPT, string melting off, rescattering on} & \quad \text{Pythia 8.1 Monash} \\
\end{align*}

\begin{align*}
\sigma_{\Delta \varphi}^{\text{Data}} & \quad \sigma_{\Delta \varphi}^{\text{MC}} \\
\sigma_{\Delta \eta}^{\text{Data}} & \quad \sigma_{\Delta \eta}^{\text{MC}}
\end{align*}

- None of the AMPT settings describe all $p_T$ bins

Monika Kofarago

Anomalous evolution of the near-side jet peak shape in Pb-Pb collisions with ALICE
**Settings:**
- string melting off, hadronic rescattering on
- string melting on, hadronic rescattering on
- string melting on, hadronic rescattering off

---

**Diagram:**
- **Initial stage**
  - String melting on
    - Strings fragment into partons
    - Partonic rescattering (ZPC)
    - Quark coalescence
    - Hadronic rescattering (ART)
    - Lund string fragmentation
  - Partons
  - Strings
- **Partonic interactions**
  - From HIJING excited strings and minijet partons

---

Monika Kofarago
Anomalous evolution of the near-side jet peak shape in Pb-Pb collisions with ALICE