Near-side jet peak broadening in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

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on behalf of the ALICE Collaboration

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arXiv:1609.06643
arXiv:1609.06667
Physics motivation

- **Goal:** study interaction of jets with the 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 $\Delta \varphi$
  - 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:

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

Trigger

Associated

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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 \((\Delta \phi, \Delta \eta) = (0,0)\) in central collisions at low \(p_T\)
Evolution of the near-side peak shape

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

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Near-side jet peak broadening in Pb-Pb collisions
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:
  \[ \sigma^2 = \frac{w^2 \Gamma\left(\frac{3}{\gamma}\right)}{\Gamma\left(\frac{1}{\gamma}\right)} \]
- 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

\[ \frac{1}{N_{\text{tag}}} \frac{d^2N_{\text{assoc}}}{d\Delta\eta d\Delta\phi} \]

ALICE, Pb-Pb
\[ \sqrt{S_{\text{NN}}} = 2.76 \text{ TeV} \]
0-10%

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

Background

Peak

Small signal over background ratio

Fit describes the data very well
Fitting illustration

ALICE, Pb-Pb
$\sqrt{s_{NN}} = 2.76$ TeV
0-10%

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

- Small signal over background ratio
- Fit describes the data very well

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Near-side jet peak broadening in Pb-Pb collisions
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 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 \( \Delta \phi \) 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: \( \sigma^2 = \frac{w^2 \Gamma(3/\gamma)}{\Gamma(1/\gamma)} \)

### Diagram 1

- ALICE
- \( \sqrt{s_{_{NN}}} = 2.76 \) TeV
- pp \( \sqrt{s} = 2.76 \) TeV

**\( \Delta \varphi \)**
- \( 1 < p_{T,\text{trig}} < 2 : 1 < p_{T,\text{assoc}} < 2 \text{ GeV/c} \)
- \( 2 < p_{T,\text{trig}} < 3 : 1 < p_{T,\text{assoc}} < 3 \text{ GeV/c} \)
- \( 3 < p_{T,\text{trig}} < 4 : 1 < p_{T,\text{assoc}} < 4 \text{ GeV/c} \)
- \( 4 < p_{T,\text{trig}} < 8 : 1 < p_{T,\text{assoc}} < 8 \text{ GeV/c} \)

**Centrality (%)**
- 20, 40, 60, 80, pp

**\( \sigma_{\Delta \varphi} \text{ (rad)} \)**

### Diagram 2

- ALICE
- \( \sqrt{s_{_{NN}}} = 2.76 \) TeV
- pp \( \sqrt{s} = 2.76 \) TeV

**\( \Delta \eta \)**
- \( 1 < p_{T,\text{trig}} < 2 : 1 < p_{T,\text{assoc}} < 2 \text{ GeV/c} \)
- \( 2 < p_{T,\text{trig}} < 3 : 1 < p_{T,\text{assoc}} < 3 \text{ GeV/c} \)
- \( 3 < p_{T,\text{trig}} < 4 : 1 < p_{T,\text{assoc}} < 4 \text{ GeV/c} \)
- \( 4 < p_{T,\text{trig}} < 8 : 1 < p_{T,\text{assoc}} < 8 \text{ GeV/c} \)

**\( \sigma_{\Delta \eta} \text{ (rad)} \)**

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

- Comparing \( \Delta \varphi \) and \( \Delta \eta \) at different centraities, it is observed that the near-side peak broadening is more pronounced in Pb-Pb collisions compared to pp collisions.

- The peak width \( \sigma^2 \) increases with decreasing centrality, indicating a stronger jet broadening in less central collisions.

- The ordering of the width according to \( p_T \) shows a clear trend: the peak broadening is more significant at lower \( p_T \) values, especially in the central and semi-central collisions.

- This trend is consistent across both \( \Delta \varphi \) and \( \Delta \eta \), highlighting the sensitivity of jet peak broadening to the transverse momentum of the jets.
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 \( \Delta \eta \)

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

Centrality (%)

\( \Delta \varphi \)

\( \sigma_{\Delta \varphi} \) (rad)

\( \Delta \eta \)

\( \sigma_{\Delta \eta} \)

Centrality (%)

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Near-side jet peak broadening in Pb-Pb collisions
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:
- Initial stage
- Partonic interactions
- Hadronization
- Hadronic interactions
AMPT

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

Initial stage

Partonic interactions

Partons

String melting off

Hadronization

Lund string fragmentation

Partonic rescattering (ZPC)

Hadronic rescattering (ART)

Hadronic interactions
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)

Partonic interactions

Quark coalescence

Hadronization

Hadronic rescattering
(ART)

Hadronic interactions
Settings:
- string melting off, hadronic rescattering on
- string melting on, hadronic rescattering on
- string melting on, hadronic rescattering off
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** $\Delta \varphi$

![Graph showing broadening in ALICE Pb-Pb collisions with $\sqrt{s_{NN}} = 2.76$ TeV.](image)

- **Much larger broadening in** $\Delta \eta$

- **Broadening most significant at intermediate** $p_T$
Quantification of the broadening ratio of width in central over peripheral:

$$\sigma_{CP, \Delta \varphi} = \frac{\sigma_{\Delta \varphi} (0-10\%)}{\sigma_{\Delta \varphi} (50-80\%)}$$

$$\sigma_{CP, \Delta \eta} = \frac{\sigma_{\Delta \eta} (0-10\%)}{\sigma_{\Delta \eta} (50-80\%)}$$

- Moderate broadening in $\Delta \varphi$
- Much larger broadening in $\Delta \eta$
Quantification of the broadening

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

- 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:

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

Data

String melting, hadronic rescattering

- ALICE
  - Pb-Pb \( \sqrt{s_{NN}} = 2.76 \text{ TeV} \)
  - AMPT
    - String melting on, rescattering on

\( \Delta \varphi \)

\( \Delta \eta \)
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\%)}
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Data

- String melting, hadronic rescattering

- String melting, hadronic rescattering

- String melting on, rescattering on

- String melting on, rescattering off

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Near-side jet peak broadening in Pb-Pb collisions
Quantification of the broadening

- **Ratio of width in central over peripheral:**

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

- **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

**Note:** none of AMPT settings describe absolute width better than 10% (see backup)
Quantification of the broadening

- **Ratio of width in central over peripheral:**

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

- **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

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

![Diagram showing data and fit for ALICE Pb-Pb collisions with different $p_T$ ranges.](image)
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 %
Near-side depletion

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

No depletion in higher $p_T$, peripheral or pp
Near-side depletion in AMPT

String melting on

Hadronic rescattering on

String melting off

Hadronic rescattering off

Generator level
Near-side depletion in AMPT

Hadronic rescattering on

String melting on

String melting off

Generator level

AMPT with hadronic rescattering on shows depletion independent of string melting

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Near-side jet peak broadening in Pb-Pb collisions
Depletion yield = $\frac{\text{Fit} - \text{Data}}{\text{Total yield}}$ in %

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>
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<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>
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</tbody>
</table>

- With hadronic rescattering describes depletion and shape evolution
- Absolute width is not described better than 10%
Are observed effects described by elliptic and/or radial flow?
0–10% fitted with Blast-wave fit to extract expansion velocity
(π: 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
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<td>AMPT string melting and hadronic rescattering</td>
<td>0.442</td>
<td>0.0412 ± 0.0002</td>
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<td>AMPT string melting</td>
<td>0.202</td>
<td>0.0389 ± 0.0002</td>
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<td>AMPT hadronic rescattering</td>
<td>0.540</td>
<td>0.0330 ± 0.0002</td>
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<td>Data*</td>
<td>0.649 ± 0.022</td>
<td>0.0364 ± 0.0003</td>
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- 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
  \((\pi: 0.5 < p_T < 1 \text{ GeV/c}, \text{K: } 0.2 < p_T < 1.5 \text{ GeV/c}, \text{p: } 0.3 < p_T < 2.0 \text{ GeV/c})\)
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**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
  \(\pi: 0.5 < p_T < 1 \text{ GeV/c}, \text{ K: } 0.2 < p_T < 1.5 \text{ GeV/c}, \text{ p: } 0.3 < p_T < 2.0 \text{ GeV/c}\)
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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
  \( (\pi: 0.5 < p_T < 1 \text{ GeV/c}, \ K: 0.2 < p_T < 1.5 \text{ GeV/c}, \ p: 0.3 < p_T < 2.0 \text{ GeV/c}) \)
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\[ \downarrow \]

- Large \( \beta_T \) is needed to describe depletion and evolution
- Likely cause of the effects is radial flow
Summary

- 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 $m_{inv} < 4$ MeV/$c^2$, $|m_{inv} - m(\Lambda)| < 5$ MeV/$c^2$ or $|m_{inv} - m(K_s^0)| < 5$ 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 $\eta$
## Systematic Uncertainties

<table>
<thead>
<tr>
<th>Source</th>
<th>$\sigma_{\Delta \phi}$</th>
<th>$\sigma_{\Delta \eta}$</th>
<th>$\sigma_{CP,\Delta \phi}$</th>
<th>$\sigma_{CP,\Delta \eta}$</th>
<th>Depletion yield</th>
</tr>
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<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><strong>Total</strong></td>
<td><strong>2.3% 4.5%</strong></td>
<td><strong>2.2% 3.6%</strong></td>
<td></td>
<td></td>
<td><strong>24–45%</strong></td>
</tr>
</tbody>
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Ranges indicate $p_T$ 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

- **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 $\Delta \varphi$

---

**Graphs:**

- $p_{T,\text{trig}} < 6$ GeV/$c$
  - $3 < p_{T,\text{assoc}} < 6$ GeV/$c$
  - $0-10\%$
  - $50-80\%$

- $\Delta \varphi$
  - $\sigma_{\Delta \varphi}$
  - $\Delta \eta$

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Monika Kofarago

Near-side jet peak broadening in Pb-Pb collisions

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Comparison to MC – absolute width in peripheral

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

![Graphs showing comparisons for ALICE and Pb-Pb, pp, and AMPT settings](image)

- String melting, hadronic rescattering
- String melting
- Hadronic rescattering

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

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

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

![Graphs showing comparison between ALICE and Monte Carlo simulations for Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, with different AMPT settings and Pythia 8.1 Monash. The graphs display the ratio of absolute widths in data and MC for different $p_T$ bins and $\Delta \varphi$ and $\Delta \eta$. The graphs highlight string melting and hadronic rescattering effects, with none of the AMPT settings accurately describing all $p_T$ bins.]
Evolution of the near-side peak shape

**High $p_T$, peripheral**

- **ALICE, Pb-Pb**
- $\sqrt{s_{NN}} = 2.76$ TeV
- 50-80% 50-80% 3 < $p_{T,\text{trig}}$ < 4 GeV/$c$
- $|\Delta \phi| < \pi/2$
- $2 < p_{T,\text{assoc}} < 3$ GeV/$c$
- $|\Delta \eta| < 1.6$
- 4% scale uncertainty

**Towards central collisions and low $p_T$:**
- Peak broadens
- Peak gets asymmetric ($\Delta \eta > \Delta \phi$)
- Depletion around ($\Delta \phi, \Delta \eta$) = (0,0) develops
**Settings:**
- string melting off, hadronic rescattering on
- string melting on, hadronic rescattering on
- string melting on, hadronic rescattering off

![Diagram of AMPT settings and processes](image-url)