there are a lot of new jet results!

<table>
<thead>
<tr>
<th></th>
<th>Perla 1st Floor</th>
<th>Casinò 1st Floor</th>
<th>Volpi 1st Floor</th>
<th>Mosaici-1 3rd Floor</th>
<th>Mosaici-2 3rd Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monday PM2</strong></td>
<td>COR</td>
<td>ELW</td>
<td>INI</td>
<td>SMA</td>
<td>QRK</td>
</tr>
<tr>
<td><strong>Tuesday AM1</strong></td>
<td>JET</td>
<td>INS</td>
<td>QHT</td>
<td>COL</td>
<td>CHI</td>
</tr>
<tr>
<td><strong>Tuesday AM2</strong></td>
<td>JET</td>
<td>QRK</td>
<td>INI</td>
<td>COL</td>
<td>SMA</td>
</tr>
<tr>
<td><strong>Tuesday PM1</strong></td>
<td>COR</td>
<td>HMU</td>
<td>THD</td>
<td>SMA</td>
<td>OHF</td>
</tr>
<tr>
<td><strong>Wednesday AM1</strong></td>
<td>JET</td>
<td>NTH</td>
<td>PHA</td>
<td>OHF</td>
<td>CHI</td>
</tr>
<tr>
<td><strong>Wednesday AM2</strong></td>
<td>JET</td>
<td>ELW</td>
<td>QHT</td>
<td>COL</td>
<td>PHA</td>
</tr>
<tr>
<td><strong>Wednesday PM1</strong></td>
<td>COR</td>
<td>INS</td>
<td>PHA</td>
<td>NTH</td>
<td>OHF</td>
</tr>
<tr>
<td><strong>Wednesday PM2</strong></td>
<td>JET</td>
<td>CHI</td>
<td>INI</td>
<td>COL</td>
<td>QRK</td>
</tr>
</tbody>
</table>

A lot of talks—this overview is incomplete!
jets in nuclear collisions—past

jet quenching observed from the earliest days of heavy ion running at the both RHIC and LHC

our task today is not to demonstrate that jets are still quenched, but to understand how these jets are modified and what that means about the inner workings of the QGP
jets in nuclear collisions—past

gjet quenching observed from the earliest days of heavy ion running at the both RHIC and LHC

our task today is not to demonstrate that jets are still quenched, but to understand how these jets are modified and what that means about the inner workings of the QGP

this demands controlled, systematic measurements & systematic theory
Strong jet suppression is observed in central Pb-Pb collisions. \( R_{AA} \) increases for more peripheral events. \( R_{AA} \) of different cone radius jets are consistent within systematic errors. Comparison with pp data at the same beam energy in ALICE has been analyzed.

Jet quenching from 50 GeV \( \rightarrow \) 1 TeV.
inclusive jets in PbPb collisions

**charging particle jets**

<table>
<thead>
<tr>
<th>$R_{AA}$</th>
<th>0 - 10%</th>
<th>50 - 80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALICE Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POWHEG+Pythia8 reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charged jets Anti-$k_T$ R=0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>\eta_{jet}</td>
<td>&lt; 0.6$ $p_{T,jet}^{max} &gt; 5$ GeV/c</td>
</tr>
</tbody>
</table>

**calorimeter jets**

<table>
<thead>
<tr>
<th>$R_{AA}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLAS anti-$k_T$, $R = 0.4$ jets, $\sqrt{s_{NN}} = 5.02$ TeV</td>
</tr>
</tbody>
</table>

Jet quenching from 50 GeV $\rightarrow$ 1 TeV

What do we know about how particles make up these jets?

Martin Spousta, Wednesday
The fragmentation functions are defined as:

\[ D(z) \equiv \frac{1}{N_{\text{jet}}} \frac{dn_{\text{ch}}}{dz} \]

\[ z \equiv \frac{p_T \cos \Delta R}{p_T^{\text{jet}}} \]

\[ D(p_T) \equiv \frac{1}{N_{\text{jet}}} \frac{dn_{\text{ch}}}{dp_T} \]
 measurement of fragmentation functions

\[ D(z) \equiv \frac{1}{N_{\text{jet}}} \frac{d n_{\text{ch}}}{d z} \]

\[ z \equiv p_T \cos \Delta R / p_T^{\text{jet}} \]

\[ D(p_T) \equiv \frac{1}{N_{\text{jet}}} \frac{d n_{\text{ch}}}{d p_T} \]
observables sensitive to the properties of the medium can be constructed. Measurements of the jet distribution of particles within the jet are a term “jet quenching”. In this paper, the fragmentation functions and the functions at fixed order to quantify di- The rapidity dependence of jet observables in Pb+Pb collisions is of great interest, in part because at e+e− collisions collected in 2015. jet energy measurement is correlated with how the jet fragments!

\[ D(z) \equiv \frac{1}{N_{\text{jet}}} \frac{d n_{\text{ch}}}{d z} \]

\[ z \equiv p_T \cos \Delta R / p_T^{\text{jet}} \]

\[ D(p_T) \equiv \frac{1}{N_{\text{jet}}} \frac{d n_{\text{ch}}}{d p_T} \]
2-dimensional unfolding

response matrix in $p_{T,\text{meas}}, p_{T,\text{true}}, z_{\text{meas}}, z_{\text{true}}$

measured

unfolded

particle z

jet $p_T$
The following sources of systematic uncertainty are considered: the jet energy scale (JES), the jet energy resolution (JER), the sensitivity of the unfolding to the prior, the residual non-closure of the analysis.

The e dependence to JER due to the steepness of the fragmentation function near size of systematic uncertainties associated with the unfolding which originate from the sensitivity of the unfolding to the shape of input MC distributions, as described in the next section.

Due to the steepness of the fragmentation function near

e lead to poorer jet energy resolution in Pb+Pb collisions than in

The magnitude of the unfolding e larger at high

effect of the unfolding is similar in

effect of the unfolding is larger at high

UE fluctuations

measured / unfolded

measured / unfolded

measured / unfolded

measured / unfolded

ATLAS

Pb+Pb, \( \sqrt{s_{NN}} = 5.02 \) TeV, 0.49 nb\(^{-1}\), 0-10%

\( pp, \sqrt{s} = 5.02 \) TeV, 25 pb\(^{-1}\)

anti-\( k \), \( R = 0.4 \) jets, \( \mid y^{\text{jet}} \mid < 2.1 \)

126 < \( p_{T}^{\text{jet}} \) < 158 GeV

\( p_{T}^{\text{jet}} \): 126 - 158 GeV

large JER centrality dependence to JER due to UE fluctuations

ATLAS

Pb+Pb, \( \sqrt{s_{NN}} = 5.02 \) TeV, 0.49 nb\(^{-1}\), 0-10%

\( pp, \sqrt{s} = 5.02 \) TeV, 25 pb\(^{-1}\)

anti-\( k \), \( R = 0.4 \) jets, \( \mid y^{\text{jet}} \mid < 2.1 \)

251 < \( p_{T}^{\text{jet}} \) < 316 GeV

\( p_{T}^{\text{jet}} \): 251-316 GeV

smaller UE effect

similar unfolding change in pp & PbPb

Martin Rybar, Wednesday

1805.05424

2 -dimensional unfolding
ratios of fragmentation functions in PbPb / pp

\[ R_D(z) = \frac{N_D\text{PbPb}}{N_Dpp} \]

**ATLAS**

\[ l_y \text{jet} \ < 2.1 \text{ anti-}k_t, R=0.4 \text{ jets} \]

- \( 126 < p_T^{\text{jet}} < 158 \text{ GeV} \)
- \( 200 < p_T^{\text{jet}} < 251 \text{ GeV} \)
- \( 316 < p_T^{\text{jet}} < 398 \text{ GeV} \)

Pb+Pb, \( \sqrt{s_{NN}} = 5.02 \text{ TeV}, 0.49 \text{ nb}^{-1}, 0\text{-10}\% \)

pp, \( \sqrt{s} = 5.02 \text{ TeV}, 25 \text{ pb}^{-1} \)
ratios of fragmentation functions in PbPb / pp

\[ R_D(z) \]

**ATLAS**

- \( 126 < p_T^{\text{jet}} < 158 \text{ GeV} \)
- \( 200 < p_T^{\text{jet}} < 251 \text{ GeV} \)
- \( 316 < p_T^{\text{jet}} < 398 \text{ GeV} \)

\( |y| < 2.1 \) anti-\( k_T \), \( R=0.4 \) jets

\( \sqrt{s_{\text{NN}}} = 5.02 \text{ TeV}, 0.49 \text{ nb}^{-1}, 0-10\% \)

\( pp, \sqrt{s} = 5.02 \text{ TeV}, 25 \text{ pb}^{-1} \)
ratios of fragmentation functions in PbPb / pp

\[ R_D(z) \]

ATLAS

\[ |y^{\text{jet}}| < 2.1 \text{ anti-} k, \ R = 0.4 \text{ jets} \]

\[ 126 < p_T^{\text{jet}} < 158 \text{ GeV} \]

\[ 200 < p_T^{\text{jet}} < 251 \text{ GeV} \]

\[ 316 < p_T^{\text{jet}} < 398 \text{ GeV} \]

Pb+Pb, \( \sqrt{s_{\text{NN}}} = 5.02 \text{ TeV}, 0.49 \text{ nb}^{-1}, 0-10\% \)

pp, \( \sqrt{s} = 5.02 \text{ TeV}, 25 \text{ pb}^{-1} \)

\[ R_D(p_T) \]

ATLAS

\[ |y^{\text{jet}}| < 2.1 \text{ anti-} k, \ R = 0.4 \text{ jets} \]

\[ 126 < p_T^{\text{jet}} < 158 \text{ GeV} \]

\[ 200 < p_T^{\text{jet}} < 251 \text{ GeV} \]

\[ 316 < p_T^{\text{jet}} < 398 \text{ GeV} \]

Pb+Pb, \( \sqrt{s_{\text{NN}}} = 5.02 \text{ TeV}, 0.49 \text{ nb}^{-1}, 0-10\% \)

pp, \( \sqrt{s} = 5.02 \text{ TeV}, 25 \text{ pb}^{-1} \)
ratios of fragmentation functions in PbPb / pp

ATLAS

$R_D(z)$

$126 < p_T^{\text{jet}} < 158 \text{ GeV}$
$200 < p_T^{\text{jet}} < 251 \text{ GeV}$
$316 < p_T^{\text{jet}} < 398 \text{ GeV}$

$R_D(p_T)$

$126 < p_T^{\text{jet}} < 158 \text{ GeV}$
$200 < p_T^{\text{jet}} < 251 \text{ GeV}$
$316 < p_T^{\text{jet}} < 398 \text{ GeV}$

Pb+Pb, $\sqrt{s_{NN}} = 5.02 \text{ TeV}, 0.49 \text{ nb}^{-1}, 0-10\%$

pp, $\sqrt{s} = 5.02 \text{ TeV}, 25 \text{ pb}^{-1}$

ATLAS

$|y^{\text{jet}}| < 2.1$ anti-$k_T$, $R=0.4$ jets
how do we look at jets?

Yi Chen, Wednesday afternoon

Level of detail

Full jet

Large structure

Constituent
how do we look at jets?

Yi Chen, Wednesday afternoon

Level of detail

Full jet

Large structure

Constituent
Level of detail

- Full jet
- Large structure
- Constituent
how do we look at jets?

Yi Chen, Wednesday afternoon

Level of detail

Full jet

Large structure

Constituent

$R_{AA}$ jet mass fragmentation functions
no significant mass modification observed in PbPb within the uncertainties
Jet grooming with soft drop

**soft drop:** recluster the jet with Cambridge-Aachen then go through the constituents and exclude the softer leg unless

\[
z_g = \frac{\min(p_{T,i}, p_{T,j})}{p_{T,i} + p_{T,j}} > z_{\text{cut}} \left( \frac{\Delta R_{ij}}{R_0} \right)^\beta
\]

Larkoski et al. 1402.2657
jet grooming with soft drop

soft drop: recluster the jet with Cambridge-Aachen then go through the constituents and exclude the softer leg unless

\[ z_g = \frac{\min(p_{T,i}, p_{T,j})}{p_{T,i} + p_{T,j}} > z_{cut} \left( \frac{\Delta R_{ij}}{R_0} \right)^\beta \]

Larkoski et al. 1402.2657

\( n_{SD} \): number of splittings which satisfy the soft drop condition
Jet grooming with soft drop

**soft drop**: reclustering the jet with Cambridge-Aachen then going through the constituents and excluding the softer leg unless

$$z_g = \frac{\min(p_{T,i}, p_{T,j})}{p_{T,i} + p_{T,j}} > z_{\text{cut}} \left( \frac{\Delta R_{ij}}{R_0} \right)^\beta$$

*Larkoski et al. 1402.2657*

exclude jet if final 2 subjets are at $\Delta R_{12} < 0.1$

(30%)

calculate mass from these two subjets
**soft drop**: recluster the jet with Cambridge-Aachen then go through the constituents and exclude the softer leg unless

\[ z_g = \frac{\min(p_{T,i}, p_{T,j})}{p_{T,i} + p_{T,j}} > z_{\text{cut}} \left( \frac{\Delta R_{ij}}{R_0} \right)^\beta \]

Larkoski et al. 1402.2657

exclude jet if final 2 subjets are at \( \Delta R_{12} < 0.1 \) (30%)

calculate mass from these two subjets

jet grooming with soft drop

1805.05145 Yi Chen, Wendnesday
the role of jet parton flavor
y dependence of inclusive jets and fragmentation functions

• why rapidity?

• fraction of quark jets increases with |y| at fixed jet $p_T$

• jet $p_T$ spectra become steeper with increasing |y|

rapidity selected spectra in pp collisions

![Graph showing rapidity selected spectra in pp collisions.](image)

**ATLAS**

2015 pp data, 25 pb$^{-1}$

anti-$k_t$, $R=0.4$ jets

$\sqrt{s} = 5.02$ TeV

$\frac{d^2\sigma}{dp_T^2 dy}$ [nb/GeV]

$\frac{d\sigma}{dy}$ [nb/GeV]

$p_T$ [GeV]

$\frac{d^2\sigma}{dp_T^2 dy}$ [nb/GeV]

$\frac{d\sigma}{dy}$ [nb/GeV]

$p_T$ [GeV]

$\frac{d^2\sigma}{dp_T^2 dy}$ [nb/GeV]

$\frac{d\sigma}{dy}$ [nb/GeV]

$p_T$ [GeV]

$\frac{d^2\sigma}{dp_T^2 dy}$ [nb/GeV]

$\frac{d\sigma}{dy}$ [nb/GeV]

$p_T$ [GeV]

$\frac{d^2\sigma}{dp_T^2 dy}$ [nb/GeV]

$\frac{d\sigma}{dy}$ [nb/GeV]

$p_T$ [GeV]

$\frac{d^2\sigma}{dp_T^2 dy}$ [nb/GeV]

$\frac{d\sigma}{dy}$ [nb/GeV]

$p_T$ [GeV]
y dependence of inclusive jets and fragmentation functions

- why rapidity?

  - fraction of quark jets increases with |y| at fixed jet $p_T$

  - jet $p_T$ spectra become steeper with increasing |y|

  - decrease RAA with |y|

- quarks jets should lose less energy than gluon jets

  - increase RAA with |y|

ATLAS

$R_{AA}(y)/R_{AA}(y<0.3) = 5.02$ TeV

anti-$k_T$, $R = 0.4$ jets, $\sqrt{s_{NN}} = 5.02$ TeV

$0 - 10\%$, $158 < p_T < 200$ GeV

$0 - 10\%$, $316 < p_T < 562$ GeV

2015 Pb+Pb data, 0.49 nb$^{-1}$

2015 pp data, 25 pb$^{-1}$
y dependence of inclusive jets and fragmentation functions

- why rapidity?
- fraction of quark jets increases with |y| at fixed jet $p_T$
- jet $p_T$ spectra become steeper with increasing |y|
  - decrease RAA with |y|
- quarks jets should lose less energy than gluon jets
  - increase RAA with |y|

ATLAS

$R_{AA}(y)|/R_{AA}(y<0.3)$

anti-$k_T$, $R = 0.4$ jets, $\sqrt{s_{NN}} = 5.02$ TeV

2015 Pb+Pb data, 0.49 nb$^{-1}$
2015 $pp$ data, 25 pb$^{-1}$
and fragmentation functions?

quark jets have more high z particles than gluon jets
and fragmentation functions?

quark jets have more high z particles than gluon jets

no significant rapidity dependence to modification of fragmentation functions
• photon-jet events dominated by $q + g \rightarrow q + \gamma$ process
• changes the flavor mix with respect to inclusive jets
• significant difference between **inclusive** and $\gamma$-tagged fragmentation functions

**Figure 3:** Fragmentation function in $pp$ events as a function of charged particle $p_T$ (left) or $z$ (right). Results are shown for the measured distribution for photon-tagged jets (black), the analogous generator-level distribution in $p_T$ events (green), and for the measured distribution for inclusive jets in a similar jet $p_T$ range (red). The shaded bands correspond to the total systematic uncertainties on the data.

ATLAS Preliminary $pp$, 26 pb$^{-1}$, 5.02 TeV

<table>
<thead>
<tr>
<th>$N_{jet}$</th>
<th>Ratio to $\gamma$+jet Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data, $\gamma$-tagged jets</td>
<td>1.0</td>
</tr>
<tr>
<td>PYTHIA 8 A14 NNPDF23LO</td>
<td>0.9</td>
</tr>
<tr>
<td>Data, inclusive jet ($p_T^{jet} = 80-110$ GeV)</td>
<td>0.8</td>
</tr>
</tbody>
</table>

 photon $p_T$: 79.6-125 GeV  
 jet $p_T$: 63.1-144 GeV

References
Figure 6: Ratio of the fragmentation function for jets azimuthally balanced with a high-photon, between that in 30–80% Pb+Pb collisions and pp collisions (left panels) and 0–30% Pb+Pb collisions and pp collisions (right panels). Results are shown as a function of charged particle $p_T$ (top panels) or $z$ (bottom panels). Hatched bands and vertical bars show the total systematic and statistical uncertainties, respectively, for each measurement.

$\xi_{\text{jet}} = \ln(1/z)$
photon-jet fragmentation functions

**Figure 1**: Top: The centrality dependence of the $x$ distribution for jets associated with an isolated photon for PbPb (full crosses) and pp (open crosses) collisions. The pp results are smeared appropriately for each PbPb centrality bin, and data for each centrality bin are shifted vertically as indicated, for clarity. Bottom: The ratios of the PbPb over smeared pp distributions. The vertical bars through the points represent statistical uncertainties, while the colored boxes indicate systematic uncertainties.

**Figure 6**: Ratio of the fragmentation function for jets azimuthally balanced with a high-$p_T$ photon, between that in 30–80% Pb+Pb collisions and pp collisions (left panels) and 0–30% Pb+Pb collisions and pp collisions (right panels). Results are shown as a function of charged particle $p_T$ (top panels) or $z$ (bottom panels). Hatched bands and vertical bars show the total systematic and statistical uncertainties, respectively, for each measurement.
photon-tagged fragmentation functions

photon $p_T$: 79.6-125 GeV
jet $p_T$: 63.1-144 GeV

ATLAS Preliminary
0-30% Pb+Pb / $pp$

Figure 4: Ratio of the fragmentation function for jets azimuthally balanced with a high-$p_T$ photon, between that in 30–80% Pb+Pb collisions and $pp$ collisions (left panels) and 0–30% Pb+Pb collisions and $pp$ collisions (right panels). Results are shown as a function of charged particle $p_T$ (top panels) or $z$ (bottom panels), for photon-tagged jets (this measurement, black points) and for inclusive jets in $p_{NN}=2.76$ TeV Pb+Pb collisions [7,14] (see text, red points). Hatched bands and vertical bars show the total systematic and statistical uncertainties, respectively, for each measurement.
photon-tagged fragmentation functions

photon $p_T$: 79.6-125 GeV
jet $p_T$: 63.1-144 GeV

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

**ATLAS** Preliminary

0-30% Pb+Pb / $pp$

Large $z_T$  
Small $z_T$
photon p$_T$: 79.6-125 GeV  
jet p$_T$: 63.1-144 GeV

γ-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$

3-4 GeV

$\gamma$-tagged jets 5.02 TeV  
inclusive jets 2.76 TeV  
(0-10%)

$\gamma$-hadron correlations at 200 GeV AuAu collisions

Joe Osborn, Wednesday

Large $z_T$  
Small $z_T$
photon-tagged fragmentation functions

photon $p_T$: 79.6-125 GeV
jet $p_T$: 63.1-144 GeV

**Figure 4**: Ratio of the fragmentation function for jets azimuthally balanced with a high-photon between that in 30–80% Pb+Pb collisions and pp collisions (left panels) and 0–30% Pb+Pb collisions and pp collisions (right panels). Results are shown as a function of charged particle $p_T$ (top panels) or $z$ (bottom panels), for photon-tagged jets (this measurement, black points) and for inclusive jets in $p_sNN = 2.76$ TeV Pb+Pb collisions [7, 14] (see text, red points). Hatched bands and vertical bars show the total systematic and statistical uncertainties, respectively, for each measurement.

Joe Osborn, Wednesday

Yield Modification in Au+Au as a Function of $p_T$ in Au+Au collisions at 200 GeV

Joe Osborn (UM)

- Transition from suppression to enhancement not at a fixed $\xi = \ln(1/z_T)$
- Suggests transition is at an approximately fixed $p_T$ in heavy ion collisions?
- Medium response in addition to redistribution of lost energy from high $p_T$ hadrons?
photon p$_T$: 79.6-125 GeV  
jet p$_T$: 63.1-144 GeV  

Figure 4: Ratio of the fragmentation function for jets azimuthally balanced with a high-photon, between that in 30–80% Pb+Pb collisions and pp collisions (left panels) and 0–30% Pb+Pb collisions and pp collisions (right panels). Results are shown as a function of charged particle p$_T$ (top panels) or z$_T$ (bottom panels), for photon-tagged jets (this measurement, black points) and for inclusive jets in $p_NN = 2.76$ TeV Pb+Pb collisions [7,14] (see text, red points). Hatched bands and vertical bars show the total systematic and statistical uncertainties, respectively, for each measurement.

Yield Modification in Au+Au as a Function of p$_T^\gamma$ as a Function of z$_T$

Large z$_T$  Small z$_T$

3-4 GeV

ATLAS Preliminary  
0-30% Pb+Pb / pp  

low p$_T$ enhancement begins at a similar p$_T$ to inclusive jets and at a similar p$_T$ between LHC and RHIC

looking forward to precision measurements with reconstructed jets at sPHENIX!
The radial distribution of tracks in a jet opposite the photon is shown in Figure 1. The colored boxes indicate systematic uncertainties in data. The ratios of the PbPb over pp distributions are depicted in the plot. The vertical lines through the points represent statistical uncertainties.

The CMS Preliminary analysis shows that for photon $p_T > 60$ GeV and jet $p_T > 30$ GeV, the ratios PbPb/pp for different pseudorapidity intervals are as follows:

- 50-100%: $5.02 \pm 0.15$ (x10)
- 30-50%: $4.03 \pm 0.20$ (x10)
- 10-30%: $3.35 \pm 0.15$ (x10)
- 0-10%: $2.50 \pm 0.10$ (x10)

The CMS data compared to PYTHIA 8 predictions is also shown in the plot.
**photon p_T: 100-158 GeV**

*ATLAS* Preliminary

*pp* 5.02 TeV, 25 pb\(^{-1}\)

Pb+Pb, 0.49 nb\(^{-1}\)

\(p_T^\gamma = 100-158\) GeV

- Blue: *pp* (same each panel)
- Red: Pb+Pb

[Graph showing photon-jet balance distributions with different centrality selections: 50-80%, 20-30%, 0-10%.]

Preliminary

ATLAS-CONF-2018-009, D Perepelitsa, Wednesday
photon $p_T$: 100-158 GeV

ATLAS Preliminary

$pp$ 5.02 TeV, 25 pb$^{-1}$
Pb+Pb, 0.49 nb$^{-1}$

$p_T^\gamma = 100-158$ GeV

$pp$ (same each panel)
Pb+Pb

increasing centrality $\rightarrow$ increasing shift to low $x_{J\gamma}$
photon $p_T$: 100-158 GeV

**ATLAS** Preliminary

$pp$ 5.02 TeV, 25 pb$^{-1}$

$Pb+Pb$, 0.49 nb$^{-1}$

$p_T^\gamma = 100$-158 GeV

$pp$ (same each panel)

$Pb+Pb$

**Increasing centrality → increasing shift to low $x_{J\gamma}$**

$50$-$80\%$

$20$-$30\%$

$0$-$10\%$

peak for nearly balanced pairs

ATLAS-CONF-2018-009, D Perepelitsa, Wednesday
20-30% Pb+Pb
$p_T^\gamma = 79.6-100$ GeV

0-10% Pb+Pb
$p_T^\gamma = 100-158$ GeV

QM ‘17

uncorrected Pb+Pb data to smeared Pythia: bulk shift...

QM ‘18

unfolded Pb+Pb-pp comparison: jets lose small/large amounts of energy!

Dennis Perepelitsa, Wednesday morning
D⁰s reconstructed in jets

15 < jet \( p_T < 30 \) GeV/c

ALICE Preliminary
pp, \( \sqrt{s} = 7 \) TeV
Charged Jets, Anti-\( k_T \), \( R = 0.4, |y| < 0.5 \)
15 < \( p_T \text{ch,jet} < 30 \) GeV/c
- Data
with \( D^0, p_T^{D^0} > 6 \) GeV/c
- Syst. Unc. (data)
- Syst. Unc. (theory)

CMS Preliminary
\( 4 < p_T^{D^0} < 20 \) GeV/c
- Data

Prompt J/\( \psi \)
\( |y| < 1.6 \)
6.5 < \( p_T^{J/\psi} < 35 \) GeV
\( |y| < 2.4 \)
\( 25 < p_T^{jet} < 35 \) GeV

D + jet

CMS Preliminary
\( D^{0 \rightarrow \pi\pi} \)
\( p_T^{D^0} > 2 \) GeV/c
\( p_T^{jet} > 60 \) GeV/c
\( |y|^{D^0} < 1.6 \)

looking forward D to measurements with higher luminosity and the ALICE upgrades

Barbara Trzeciak, Tuesday

XeXe collisions in LHC, 13 October 2017

Papers at IPAC2018

https://ipac18.org
http://ipac2018.vrws.de

MOPMF039
First XeXe Collisions in the LHC

MOPMF038
Cleaning Performance of the Collimation System with Xe Beams at the Large Hadron Collider

TUPAF020
Performance of the CERN Low Energy Ion Ring (LEIR) with Xe

TUPAF024
Impedance and Instability Studies in LEIR With Xe

Future interest in lighter species?
jets and high pt charged particles in XeXe quenched according to $\sim N_{\text{part}}/\text{multiplicity}$
The dijet asymmetry

\[ x_J = \frac{p_{T_2}}{p_{T_1}} \]

Figure 7

\[ 2.05 < \Sigma E_{T}^{FCal} < 2.99 \text{ TeV} \]

\[ 0.3 \leq x_{J,\text{meas}} \leq 1 \]

\[ \text{Xe+Xe smeared to Pb+Pb} \]

\[ \text{Pb+Pb, } \sqrt{s_{NN}} = 5.02 \text{ TeV} \]

\[ \text{Xe+Xe, } \sqrt{s_{NN}} = 5.44 \text{ TeV} \]

\[ \text{anti-}k_t, R = 0.4 \text{ jets} \]

\[ \text{ATLAS Preliminary} \]
dijet balance XeXe, PbPb, AuAu

\[
X_J = \frac{p_{T2}}{p_{T1}}
\]

\[A_J = \frac{(p_{T\text{lead}} - p_{T\text{sublead}})}{(p_{T\text{lead}} + p_{T\text{sublead}})}\]

ATLAS Preliminary

anti-\(k_t\), \(R = 0.4\) jets

- Xe+Xe, \(\sqrt{s_{NN}} = 5.44\) TeV
- Pb+Pb, \(\sqrt{s_{NN}} = 5.02\) TeV
- Xe+Xe smeared to Pb+Pb

STAR Preliminary

Run 14 0-20%
Run 14 20-40%
Run 14 50-70%

\(p_{T\text{const}} > 2.0\) GeV/c
\(p_{T\text{lead}} > 20.0\) GeV/c
\(p_{T\text{sublead}} > 10.0\) GeV/c

ATLAS-CONF-2018-007, Spousta Wednesday
The other nucleus. The variables fact that in a given nucleus–nucleus collision, a nucleon may interact with more than one nucleon from

where

The dijet asymmetry from such comparisons without resorting to a full unfolding or detector response.

systems have similar degree of overlap— as well as common intervals of total forward transverse energy— and Pb+Pb results are compared using common collision centrality intervals—for which the two colliding compare observables sensitive to jet quenching between di

be expected to a

symmetric. The decrease in the number of nucleons or the nuclear radius between Pb and Xe nuclei may

the underlying event is smaller in the most central collisions where the collision geometry is the most

insight into the physics of parton energy loss in the quark-gluon plasma.

\[ \mathcal{A}_J = \frac{p_{T_{\text{lead}}}}{p_{T_{\text{sublead}}}} \]

The products of the

1 Introduction

ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector

\[ \text{ATLAS Preliminary} \]

\[ \text{anti-}\kappa_t, R = 0.4 \text{ jets} \]

\[ \text{Xe+Xe, } \sqrt{s_{\text{NN}}} = 5.44 \text{ TeV} \]

\[ \text{Pb+Pb, } \sqrt{s_{\text{NN}}} = 5.02 \text{ TeV} \]

\[ -\text{Xe+Xe smeared to Pb+Pb} \]

\[ \text{2.05} < \Sigma E_{\text{T}}^{\text{FCal}} < 2.99 \text{ TeV} \]

\[ \chi_{J}^{\text{meas}} \]

\[ \frac{1}{N} \frac{dN}{dx_{\chi J}} \]

\[ \mathcal{A}_J = \frac{p_{T_{\text{lead}}}}{p_{T_{\text{sublead}}}} \]

\[ \text{STAR Preliminary} \]

\[ \text{Run 14 0-20\%} \]

\[ \text{Run 14 20-40\%} \]

\[ \text{Run 14 50-70\%} \]

looking forward to doing this comparison over a wider kinematic range at RHIC with sPHENIX!
lighter ions could provide more jets at the LHC

Gains in ULTIMATE integrated nucleon-nucleon luminosity PER FILL wrt Pb-Pb

This would be on the assumption that a fill would be kept forever until one beam was exhausted (and other loss mechanisms are neglected). Real gain/fill will be less.

In reality, one also gains from longer luminosity lifetime and less time spent refilling the machine.

We will try to quantify this better in future.

John Jowett, Tuesday morning
Jet Rates and Physics Reach Scientific Objective and Performance

Figure 1.22 summarizes the current and future state of hard probes measurements in A+A collisions in terms of their statistical reach, showing the most up to date $R_{AA}$ measurements of hard probes in central Au+Au events by the PHENIX Collaboration plotted against statistical projections for sPHENIX channels measured after the first two years of data-taking. While these existing measurements have greatly expanded our knowledge of the QGP created at RHIC, the overall kinematic reach is constrained to <20 GeV even for the highest statistics measurements. Figure 1.23 shows the expected range in $p_T$ for sPHENIX as compared to measurements at the LHC. Due to the superior acceptance, detector capability and collider performance, sPHENIX will greatly expand the previous kinematic range studied at RHIC energies (in the case of inclusive jets, the data could extend to 80 GeV/c, four times the range of the current PHENIX $p_0$ measurements) and will allow access to new measurements entirely (such as fully reconstructed $b$-tagged jets).

looking forward to sPHENIX in 2023

measurements we are making now will help us understand sPHENIX data when it comes
looking forward

• as a community, much experience with modified jets in AA collisions

• at this conference: many innovate & systematic measurements

• what we need going forward:
  
  • consistent theory calculations over a wide range of observables and an understanding of what we learn from them

  • great to see the wealth of theory comparisons in talks/papers/notes and the release of JETSCAPE

• focus on high quality measurements that are comparable between experiments (now and in the future) and with theory
looking forward

• as a community, much experience with modified jets in AA collisions

• at this conference: many innovate & systematic measurements

• what we need going forward:

  • consistent theory calculations over a wide range of observables and an understanding of what we learn from them

  • great to see the wealth of theory comparisons in talks/papers/notes and the release of JETSCAPE

  • focus on high quality measurements that are comparable between experiments (now and in the future) and with theory

both of these are necessary to make sure that we get the full benefit of the tremendous resources (time and money) that we are putting into heavy ion running over the next decade
backup
Figure 23: Difference between Pb+Pb collisions and pp collisions in the total yield of charged particles, $N_{ch}^{|cent|}$, (left) and difference in the total transverse momentum carried by charged particles, $P_{T}^{ch}$, (right) for particles with $p_{T} < 4.2$ GeV evaluated as a function of $p_{T}^{jet}$ for six centrality intervals. The vertical bars on the data points indicate statistical uncertainties while the boxes indicate systematic uncertainties.
angular structure of jets

Jet axis

Rybar, Wed.
Jet axis

Angular structure of jets

ATLAS measurements at 2 different energies and 3 colliding systems:

- pp @ 5 TeV & 2.76 TeV
- p+Pb @ 5 TeV
- Pb+Pb @ 5 TeV & 2.76 TeV

Measurement of fragmentation functions (FF), where \( r < 0.6 \)

Rybar, Wed.
low momentum particles: broad angular distribution which extends far outside the jet