Photon-tagged measurements of jet quenching with ATLAS

Dennis V. Perepelitsa
(University of Colorado Boulder)
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Run: 286834
Event: 124877733
2015-11-28 01:15:42 CEST
Pb+Pb $\sqrt{s_{NN}} = 5.02$ TeV
photon + multijet event
$\sum E_T^{\text{FCal}} = 4.06$ TeV

$\rho_T = 200$ GeV
photon

balancing jet(s)?
What is the (absolute) amount of energy lost in cone?

*Photon* + *jet* $p_T$-balance

$\Rightarrow \ x_{J\gamma} = \frac{p_{Tjet}}{p_{T\gamma}} \ (for \ \Delta \phi > 7\pi/8)$
What is the (absolute) amount of energy lost in cone?

\[ x_{J\gamma} = \frac{p_{T\text{jet}}}{p_{T\gamma}} \quad (\text{for } \Delta\phi > \frac{7\pi}{8}) \]

How is the parton shower in cone modified by medium?

\[ D(p_{Th}) \text{ or } D(z = \frac{p_{Th}}{p_{T\text{jet}}}) \]
What is the (absolute) amount of energy lost in cone?

Photon + jet $p_T$-balance

$\rightarrow x_{J\gamma} = \frac{p_T^{\text{jet}}}{p_T^{\gamma}}$ (for $\Delta \phi > 7\pi/8$)

How is the parton shower in cone modified by medium?

Photon-tagged frag. function (with respect to the jet)

$\rightarrow D(p_T^{h})$ or $D(z = \frac{p_T^{h}}{p_T^{\text{jet}}})$

NEW @ ATLAS-CONF-2018-009

NEW @ ATLAS-CONF-2017-074
Photons, jets, hadrons

Photons in EMCal
$\rho_T > 63.1$ GeV, $|\eta| < 2.37$
(excluding 1.37-1.56)

Z. Citron, 10:00am

Jets in calorimeter
$|\eta| < 2.8$, $\rho_T > 31.6$ GeV

M. Spousta, 11:10am

Tracks in inner detector ($|\eta| < 2.5$)

M. Rybář, 12:30pm

Centrality in FCal (3.2 < $|\eta|$ < 4.9)
Correction for detector effects

- 2-D unfolding in \((p_T^\gamma, x_{J_\gamma})\)
  \(\Rightarrow (p_T^{\text{jet}}, p_T^h)\) or \((p_T^{\text{jet}}, z)\) for FF measurement

\[ \text{big "blocks" show the} \]
\((p_T^{\text{truth}, \gamma}, p_T^{\text{reco}, \gamma})\) \text{correlation at fixed} \((p_T^{\text{truth}, \gamma}, p_T^{\text{reco}, \gamma})\)

\[ \Rightarrow \text{final results at "particle level"} \]
What is the (absolute) amount of energy lost in cone?

Photon + jet \( p_T\)-balance

\[ x_{J\gamma} = \frac{p_T^{jet}}{p_T^{\gamma}} \] (for \( \Delta\phi > 7\pi/8 \))
Photon+jet $p_T$ balance in $pp$

Compare directly to MC generators: **Pythia 8 Sherpa Herwig 7**

unfolding recovers sharp peak…

\[ \rho_T = 63.1-79.6 \text{ GeV} \]

\[ \rho_T = 100-158 \text{ GeV} \]

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

Data

Pythia A14 NNPDF23LO

Sherpa CT10

Herwig H7UE MMHT2014lo

unfolding recovers sharp peak…

\[ (1/N_J)(dN/dx_J) \]

\[ (1/N_J)(dN/dx_J) \text{ Ratio of } (1/N_J)(dN/dx_J) \]

\[ x_J \]

\[ x_J \text{ Ratio of } x_J \]
Pb+Pb, $p_T^\gamma = 63.1-79.6$ GeV

**ATLAS** Preliminary

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

$p_T^\gamma = 63.1-79.6$ GeV

$pp$ (same each panel)
Pb+Pb

peaked structure destroyed in **0-10% Pb+Pb**
Pb+Pb, $p_{T\gamma} = 63.1-79.6$ GeV

$\gamma$-ray production is shown for different centralities in $pp$ and Pb+Pb collisions.

**ATLAS** Preliminary

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

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

$p_{T\gamma} = 63.1-79.6$ GeV

$\gamma$-ray production is observed to be suppressed in Pb+Pb collisions compared to $pp$.

Peaked structure destroyed in 0-10% Pb+Pb
peak returns in **50-80%** Pb+Pb events

\( \text{Pb+Pb, } p_{T\gamma} = 63.1-79.6 \text{ GeV} \)

**ATLAS** Preliminary

- **pp 5.02 TeV, 25 pb\(^{-1}\)**
- **Pb+Pb, 0.49 nb\(^{-1}\)**

\( p_{T\gamma} = 63.1-79.6 \text{ GeV} \)

**\( p_{T}\gamma \)** (same each panel)

- **pp**
- **Pb+Pb**

peaked structure destroyed in **0-10%** Pb+Pb
Pb+Pb, $p_T^\gamma = 79.6-100$ GeV

**ATLAS** Preliminary

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

$p_T^\gamma = 79.6-100$ GeV

$\langle 1/N_j \rangle (dN/dx_j)_{PP} (\text{same each panel})$

$\langle 1/N_j \rangle (dN/dx_j)_{Pb+Pb}$

Peaked structure (jets w/o E-loss?) visible in $20-30\%$
$50-80\%$ Pb+Pb events compatible with $pp$

$\text{Pb+Pb, } p_T^\gamma = 100-158 \text{ GeV}$

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

$p_T^\gamma = 100-158 \text{ GeV}$

$p_T (\text{same each panel})$

$pp$ (same each panel)

$\text{Pb+Pb}$

visible peak even in $0-10\%$ Pb+Pb
Fix centrality, explore $\rho_{T\gamma}$-evolution

Higher $\rho_{T\gamma}$
Fix centrality, explore $\rho_{T^\gamma}$-evolution

higher $\rho_{T^\gamma}$
20-30% Pb+Pb
$p_T^\gamma = 79.6-100$ GeV

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

uncorrected $Pb+Pb$ data to smeared Pythia: bulk shift...
20-30% Pb+Pb
$p_T^γ = 79.6-100$ GeV

0-10% Pb+Pb
$p_T^γ = 100-158$ GeV

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

QM '17

QM '18

unfolded Pb+Pb-pp comparison: jets lose small/large amounts of energy!
Direct comparisons to theory (no smearing)

Test description of vacuum ($pp$) baseline

Can models describe centrality / $p_T\gamma$ evolution?
How is the parton shower in cone modified by medium?

**Photon**-tagged **frag. function** (with respect to the **jet**)

\[ D(p_T^h) \text{ or } D(z = \frac{p_T^h}{p_T^{\text{jet}}}) \]
How is the parton shower in cone modified by medium?

Photon-tagged frag. function (with respect to the jet)

$\rightarrow D(p_T^h) \text{ or } D(z = p_T^h / p_T^{jet})$

Kinematic selection intended to pick out only the leading (dominantly quark) jet:

$\begin{align*}
    p_T^\gamma &= 79.6-125 \text{ GeV} \\
    p_T^{jet} &= 63.1-144 \text{ GeV}
\end{align*}$
\( \gamma \)-tagged jet FF in \( pp \)

- **\( \gamma \)-tagged jet** (quark jet-dominant)
- **Inclusive jet** (gluon jet-dominant)

\[ \frac{1}{N_{\text{jet}}} \frac{dN}{dz} \]

**ATLAS** Preliminary

\( pp, 26 \text{ pb}^{-1}, 5.02 \text{ TeV} \)

- Data, \( \gamma \)-tagged jets
- PYTHIA 8 A14 NNPDF23LO
- Data, inclusive jet \( (p_T^{\text{jet}} = 80-110 \text{ GeV}) \)
$\gamma$-tagged jet FF in $pp$

$\gamma$-tagged jet
(quark jet-dominant)

Inclusive jet
(gluon jet-dominant)

Inclusive / $\gamma$-tagged ratio
**γ-tagged jet FF in pp**

Fragmentation difference as expected from, e.g. LEP

Inclusive / γ-tagged ratio

(also γ-tagged Pythia/data ratio)
\( \gamma \)-tagged jet FF ratios in Pb+Pb

30-80\% Pb+Pb / pp

\[ \frac{D(\tau)}{P_{\text{p}}^{0.6}} \]

\[ \frac{D(\tau)}{P_{\text{p}}^{0.8}} \]

\[ \frac{D(\tau)}{P_{\text{p}}^{1.0}} \]

\[ \frac{D(\tau)}{P_{\text{p}}^{1.2}} \]

\[ \frac{D(\tau)}{P_{\text{p}}^{1.4}} \]

\[ \frac{D(\tau)}{P_{\text{p}}^{1.6}} \]

\[ \frac{D(\tau)}{P_{\text{p}}^{1.8}} \]

\[ \frac{D(\tau)}{P_{\text{p}}^{2.0}} \]

\( \gamma \)-tagged jets 5.02 TeV

**ATLAS** Preliminary

30-80\% Pb+Pb / pp

familiar pattern of modification here…
γ-tagged jet FF ratios in Pb+Pb

30-80% Pb+Pb / pp

0-30% Pb+Pb / pp

Compare to unfolded inclusive jet FF measurement @ 2.76 TeV…

(new 5.02 TeV results: M. Rybář, this room, 12:30pm)

familiar pattern of modification here…

… different pattern here!
γ-tagged jet FF ratios in Pb+Pb

30-80% Pb+Pb / pp

0-30% Pb+Pb / pp

Compare to unfolded inclusive jet FF measurement @ 2.76 TeV…

Inclusive vs. γ-tagged FF’s modified differently!

familiar pattern of modification here…

… different pattern here!
$\gamma$-tagged jet FF ratios in Pb+Pb

**0-30% Pb+Pb / pp**

**30-80% Pb+Pb / pp**

more enhancement at low-$p_T^h$

shift of mid-$p_T^h$ minimum,

no enhancement at large-$p_T^h$!

**$\gamma$-tagged jet** FF vs. inclusive jet FF:

**familiar pattern of modification here…**

… **different pattern here!**
\textbf{\gamma\text,-tagged jet} FF vs. inclusive jet FF

\begin{itemize}
\item \textbf{30-80\% Pb+Pb / pp} \hfill \textbf{0-30\% Pb+Pb / pp} \hfill \textbf{0-30\% / 30-80\%}
\end{itemize}

\begin{align*}
\text{ratio of } &D(p_T) \\
&\text{\gamma\,-tagged jets 5.02 TeV} \\
&\text{inclusive jets 2.76 TeV} \\
&(30-40\%) \\
&\text{\gamma\,-tagged jets 5.02 TeV} \\
&\text{inclusive jets 2.76 TeV} \\
&(0-10\%) \\
&\text{\gamma\,-tagged jets 5.02 TeV} \\
&\text{inclusive jets 2.76 TeV} \\
&(0-10\% / 30-40\%)
\end{align*}

\textit{ATLAS} Preliminary

\begin{itemize}
\item \textbf{30-80\% Pb+Pb / pp} \hfill \textbf{0-30\% Pb+Pb / pp} \hfill \textbf{0-30\% / 30-80\%}
\end{itemize}

\begin{itemize}
\item Stronger centrality dependence for how \text{\gamma\,-tagged jets} are modified
\end{itemize}
γ-tagged jet quenching (w/ unfolding for detector effects)

- γ+jet $p_T$-balance
  - **pp-like peaked** $x_{Jγ}$ in Pb+Pb:
    variation in jet-by-jet $E$-loss

*ATLAS* Preliminary

- $pp$ 5.02 TeV, 25 pb$^{-1}$
- Pb+Pb, 0.49 nb$^{-1}$
- $p_T^γ = 79.6-100$ GeV
- $pp$ (same each panel)
- Pb+Pb
γ-tagged jet quenching (w/ unfolding for detector effects)

- γ+jet $p_T$-balance
  - pp-like peaked $x_J\gamma$ in Pb+Pb: variation in jet-by-jet $E$-loss

- γ-tagged jet frag. functions:
  - different modification in central evts. than inclusive jets
γ-tagged jet quenching (w/ unfolding for detector effects)

- γ+jet $p_T$-balance
  - **pp-like peaked** $x_{Jγ}$ in Pb+Pb: variation in jet-by-jet $E$-loss

- γ-tagged jet frag. functions:
  - different modification in central evts. than inclusive jets

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults

ATLAS-CONF-2018-009
ATLAS-CONF-2017-074

50-80% 20-30% 0-10%

- ATLAS Preliminary
  - pp 5.02 TeV, 25 pb⁻¹
  - Pb+Pb, 0.49 nb⁻¹
  - $p_T^γ = 79.6-100$ GeV
  - pp (same each panel)
  - Pb+Pb

- ratio of $D(p_T)$
  - γ-tagged jets 5.02 TeV
  - inclusive jets 2.76 TeV
  - (0-10%)
backup
1. What is the (absolute) amount of energy lost in cone?
   - $\text{photon} + \text{jet} \ p_T$-balance

2. How is the parton shower in cone modified by medium?
   - $\text{photon}$-tagged $\text{frag. function}$ (with respect to the $\text{jet}$)

3. Where does the lost energy go?
   - $\text{photon}$-$\text{hadron}$ corr. broadly in angle / momentum
Systematic uncertainties (on $x_{J\gamma}$)

- **Dominant**: standard HI jet $p_T$ scale, resolution uncertainties
- **Sub-dominant**: photon ID, isolation, dijet background
- **Co-dominant in central events**: prior/MC/combinatoric bkg.

$\Rightarrow$ FF measurement also includes tracking uncertainties
Photon selection

- Photons are required to pass ID cuts & be experimentally isolated
  - purity estimated with standard “double sideband” approach,
    >95% (>80%) in pp (central Pb+Pb)
Data-driven background corrections

- **combinatoric** photon+jet pairs
- **dijets** ($\pi^0$+jet) from impure photon selection
- FF measurement also includes UE particles in jet cone
Photon-jet $p_T$ balance in $pp$: additional $p_T^\gamma$ bins
ATLAS measurements with 2-D unfolding

→ needed to reveal otherwise hidden physical features of distributions

\[ \frac{1}{N} \frac{dN}{dx_j} \]

\[ R = 0.4 \text{ jets} \]

\[ \sqrt{s_{NN}} = 2.76 \text{ TeV} \]

\[ 0 - 10 \% \]

\[ 100 < p_{T1} < 126 \text{ GeV} \]

\[ 0 - 10 \% \]

\[ 100 < p_{T1} < 126 \text{ GeV} \]

\[ 0 - 10 \% \]

\[ R_{D(p_T)} \]

\[ \text{Pb+Pb 0-10\%} \]

\[ |y| < 2.1 \]

\[ 1 \text{ jet} \]

\[ 0.3 \text{ jets} \]

\[ 0.14 \text{ nb} \]

\[ 4.0 \text{ pb}^{-1} \]

\[ 2011 \text{ Pb+Pb data} \]

\[ 2013 \text{ pp data} \]

\[ x_j \]

\[ p_T [\text{GeV}] \]
Effect of unfolding on ... inclusive jet fragmentation functions

Effect of unfolding on … dijet $p_T$-asymmetry
Figure 6: Photon–jet $p_T$ balance distributions $(1/N_\gamma)(dN/dx_{J\gamma})$ in $pp$ events (blue, reproduced on all panels) and Pb+Pb events (red) with each panel denoting a different centrality selection. These panels show results with $p_T = 100–158$ GeV. Total systematic uncertainties are shown as boxes, while statistical uncertainties are shown with vertical bars.

Figure 7: Photon–jet $p_T$ balance distributions $(1/N_\gamma)(dN/dx_{J\gamma})$ in $pp$ events (blue, reproduced on all panels) and Pb+Pb events (red) with each panel denoting a different centrality selection. These panels show results with $p_T = 158–200$ GeV. Total systematic uncertainties are shown as boxes, while statistical uncertainties are shown with vertical bars.

$\textbf{ATLAS}$ Preliminary

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

$\gamma_T = 158-200$ GeV

- $pp$ (same each panel)
- Pb+Pb

15th May 2018 – 07:43
$R_\gamma = \text{fraction of photons with leading jet } x_{J\gamma} > 0.5$

$R_\gamma(\text{Pb+Pb}) - R_\gamma(\text{pp})$

(with common systematics cancelled)

$\Delta R_\gamma = -0.15 \text{ to } -0.20 \text{ in } 0-10\% \text{ events}$
\( <x_{J\gamma}> = \text{truncated mean } x_{J\gamma} \)
of leading jets with \( x_{J\gamma} > 0.5 \)

\( <x_{J\gamma}>^{(\text{PbPb})} - <x_{J\gamma}>^{(pp)} \)
(can be interpreted as per-jet fractional energy loss)

\( \Delta <x_{J\gamma}> = -0.07 \text{ to } -0.06 \)
in 0-10% events
Mean $p_T$ response vs. $p_T$

Mean $p_T$ resolution vs. $p_T$

response vs. reaction plane

Comparisons to theory (higher-$p_T\gamma$)

![ATLAS Preliminary](p_p_data.png)

**ATLAS Preliminary**
5.02 TeV, 25 pb$^{-1}$
$p_T^{\gamma} = 100-158$ GeV

- **$pp$**
- **BDMPS-Z**
- **JEWEL+PYTHIA**
- **Hybrid**

![ATLAS Preliminary](pb_pb_data.png)

**ATLAS Preliminary**
5.02 TeV, 0.49 nb$^{-1}$
$p_T^{\gamma} = 100-158$ GeV

- **Pb+Pb 0-10%**
- **BDMPS-Z**
- **(\tilde{q}=2-8$ GeV$^2$/fm)**
- **JEWEL+PYTHIA**
- **Hybrid**

**0-10% Pb+Pb**
Correction for detector effects

Figure 12: Representation of the response for pp events (left) and 0–10% Pb+Pb events (right). Each large sub-region represents a fixed value of $(p_T^{\gamma}, \text{truth}), (p_T^{\gamma}, \text{reco})$, while the small bins within them represent the $(x_J^{\text{truth}}, x_J^{\text{reco}})$ response.

The insets show a closeup of the $x_J$ response for an example $(p_T^{\gamma}, \text{truth}), (p_T^{\gamma}, \text{reco})$ selection (dashed square).

Figure 13: Selected comparison of the nominal results in pp (blue) and 0-10% Pb+Pb (red) collisions to the central values obtained using a different photon–jet signal definition. Left: Comparison of the nominal results (with $\pi/8 > 7$) with those obtained using $\pi/4 > 3$ for the $p_T^{\gamma} = 63.1-79.6$ GeV selection. Right: Comparison of the nominal results (inclusive jet selection) with those obtained using a photon plus leading jet selection for the $p_T^{\gamma} = 100-158$ GeV selection. Boxes indicate total systematic uncertainties, while vertical bars indicate statistical uncertainties.
Cross-check with alternate fiducial definitions

Open $\Delta \Phi$ window from $>7\pi/8$ to $>3\pi/8$  

Select leading jet only instead of all jets with $\Delta \Phi > 7\pi/8$
Photon-tagged measurements possible in Run 2:

1. $\gamma + \text{jet}$: absolute $E$-loss
2. $D(z)$ for $\gamma$-tagged jets in Pb+Pb & $p+p$
3. $\gamma$-tagged $R_{AA}$
4. $\gamma + \text{jet}$ vs. reaction plane
5. missing-$p_T$ flow w/ external scale

→ https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults ←
Large differences for inclusive vs. leading at low-\(x_{J/\gamma}\)...
Sensitivity to analysis choices…

1. Photon + *inclusive* jets
   - experimentally easy, but can’t extract per-jet $<E_{\text{loss}}>$

2. Photon + *leading* jet
   - better-defined “leading quark” probe

3. Photon + $\Sigma p_T$ of high-$p_T$ jets
   - $E$-loss of entire recoiling hadronic system
vary system size

ATLAS Preliminary

5.02 TeV Pb+Pb, 0.49 nb⁻¹

Data Simulation

50-80% Pb+Pb
30-50% Pb+Pb
20-30% Pb+Pb
10-20% Pb+Pb
0-10% Pb+Pb

γ x /dN (dγ x N)/(1/γ x )/dN
\[ p_{T\gamma} = 79.6-125 \text{ GeV} \]

\[ p_{T} \]

\[ p_{T}\text{jet} = 63.1-144 \text{ GeV} \]

- no jets with \( x_{J\gamma} < 0.5 \) accepted (only leading jets)

- 73-83\% quark-initiated jets
ATLAS Preliminary
5.02 TeV, γ-tagged jets

$D(p_T)$

$D(z)$
\[ D(p_T) \]

\[ D(z) \]
\textbf{γ-tagged}

\begin{tabular}{ccc}
\textbf{30-80\% / pp} & \textbf{0-30\% / pp} & \textbf{0-30\% / 30-80\%} \\
\end{tabular}

\begin{tabular}{ccc}
\textbf{D(\(p_T\))} & \textbf{D(z)} & \textbf{D(z)} \\
\end{tabular}

\begin{tabular}{ccc}
\textbf{ATLAS Preliminary} & \textbf{ATLAS Preliminary} & \textbf{ATLAS Preliminary} \\
\textbf{30-80\% Pb+Pb / pp} & \textbf{0-30\% Pb+Pb / pp} & \textbf{0-30\% Pb+Pb / 30-80\% Pb+Pb} \\
\end{tabular}
\( \gamma \)-tagged

inclusive

\[ D(\rho_T) \]

\[ D(z) \]
\[ \gamma_T/p_T^{\text{jet}} = \gamma_j \times \frac{dN}{d\gamma_j} \]

CMS \( \gamma_T/p_T^{\text{jet}} \) \( \gamma_j \)

- Red: PbPb 0 - 30%
- Green: pp (smeared)

**Graph Details:**
- **PbPb 0 - 30%**:
  - \( p_T^{\text{jet}} \in (40,50) \) GeV/c
  - \( p_T^{\text{jet}} \in (50,60) \) GeV/c
  - \( p_T^{\text{jet}} \in (60,80) \) GeV/c
  - \( p_T^{\text{jet}} > 100 \) GeV/c

**Graph Settings:**
- CMS, pp 27.4 pb\(^{-1}\), \( \sqrt{s_{\text{NN}}} = 5.02 \) TeV, PbPb 404 \( \mu \)b\(^{-1}\)
- \( p_T^{\text{jet}} > 30 \) GeV/c, \( |\eta_{\text{jet}}| < 1.6 \), \( |\Delta\phi_{\gamma j}| > \frac{7\pi}{8} \)
- \( x_{\gamma j} = p_T^{\text{jet}}/p_T^{\gamma} \)

**Legend:**
- PbPb 0 - 30%
- pp (smeared)
CMS

$\sqrt{s_{\text{NN}}} = 5.02$ TeV, PbPb 404 $\mu$b$^{-1}$, pp 27.4 pb$^{-1}$

- $p_T > 60$ GeV/c, $|\eta| < 1.44$, $\Delta\phi > 7\pi/8$
- anti-$k_T$ jet $R = 0.3$, $p_T^{\text{jet}} > 30$ GeV/c, $|\eta^{\text{jet}}| < 1.6$
- $p_T^{\text{trk}} > 1$ GeV/c

$1/N^{\text{jet}} dN^{\text{trk}}/d\xi^{\text{jet}}$

Preliminary ATLAS

- $p_T > 60$ GeV/c, $|\eta| < 1.44$, $\Delta\phi > 7\pi/8$
- anti-$k_T$ jet $R = 0.3$, $p_T^{\text{jet}} > 30$ GeV/c, $|\eta^{\text{jet}}| < 1.6$
- $p_T^{\text{trk}} > 1$ GeV/c

Preliminary ATLAS

- $p_T > 60$ GeV/c, $|\eta| < 1.44$, $\Delta\phi > 7\pi/8$
- anti-$k_T$ jet $R = 0.3$, $p_T^{\text{jet}} > 30$ GeV/c, $|\eta^{\text{jet}}| < 1.6$
- $p_T^{\text{trk}} > 1$ GeV/c
CMS

$p_T > 60 \text{ GeV/c}, |\eta| < 1.44, \Delta \phi > 7\pi/8$

anti-$k_T$ jet $R = 0.3$, $p_T^{\text{jet}} > 30 \text{ GeV/c}, |\eta^{\text{jet}}| < 1.6$

$p_T > 1 \text{ GeV/c}$

$\sqrt{s_{NN}} = 5.02 \text{ TeV}, \text{ PbPb} 404 \mu b^{-1}, pp 27.4 \text{ pb}^{-1}$

$1$/$N^{\text{jet}}$d$N^{\text{trk}}$/d$\xi_T$ $\gamma$

$\gamma$-tagged jets 5.02 TeV

$[0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8]$

$\text{CMS}$

$\text{ATLAS Preliminary}$

$\text{PP}$

$\text{PbPb} / pp$

$[0.5, 1.5, 2.5, 3.5, 4.5]$

$\text{ATLAS Preliminary}$

$p_T$ [GeV]

$p_T$ [GeV]
Teaser comparisons to theory...

Hybrid model (0-30%, vs. $p_T$) with back-reaction

SCET<sub>G</sub> calculation (0-30%, vs. $z$)
$R_D(z)$

ATLAS

$|y^{\text{jet}}| < 2.1$ anti-$k_T$, $R=0.4$ jets

- $126 < p_T^{\text{jet}} < 158 \text{ GeV}$, $\sqrt{s_{\text{NN}}} = 2.76 \text{ TeV}$
- $126 < p_T^{\text{jet}} < 158 \text{ GeV}$, $\sqrt{s_{\text{NN}}} = 5.02 \text{ TeV}$

$R_D(p_T)$

ATLAS

$|y^{\text{jet}}| < 2.1$ anti-$k_T$, $R=0.4$ jets

- $126 < p_T^{\text{jet}} < 158 \text{ GeV}$, $\sqrt{s_{\text{NN}}} = 2.76 \text{ TeV}$
- $126 < p_T^{\text{jet}} < 158 \text{ GeV}$, $\sqrt{s_{\text{NN}}} = 5.02 \text{ TeV}$

$\text{Pb+Pb, 0-10\%}$