

Photon and jet probes of small systems in ATLAS



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Hard processes in p+Pb collisions



- Modification of PDFs in nuclei, initial state energy loss, etc.
- Non-linear QCD effects: angular broadening, monojet production, etc.
- In this talk: recent photon/jet measurements in 2016 p+Pb data
 - All results at: <u>https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults</u>

Photons in EM Barrel ($|\eta| < 1.37$) and EM Endcap (1.56 < $|\eta| < 2.37$)





R=0.4 jets in calorimeter system ($|\eta| < 4.9$)

+ High-level trigger system sampling 162/nb of 8.16 TeV and 0.36/nb of 5.02 TeV *p*+Pb data

Prompt photons in p+Pb collisions (nucl-ex/1903.02209)

- Results on Z/W in Pb+Pb shown by M. Dumancic (ATLAS) + others
 - ➡ Z's, W's only probe Q² > m_{W/Z²}, and probe primarily quark nPDFs
 - Photons probe lower-Q², give access to nuclear gluons
- Full statistics, 8.16 TeV p+Pb data
- Measurement presented here is centrality-integrated (0-100%)



Photon+multijet event $p+Pb \sqrt{s_{NN}} = 8.16 \text{ TeV}, \sum E_T^{Pb} = 33.1 \text{ GeV}$ photon: $p_T = 154 \text{ GeV}, \eta = -2.07, \phi = 2.96$ jet 1: $p_T = 214 \text{ GeV}, \eta = 0.63, \phi = 0.58$ jet 2: $p_T = 110 \text{ GeV}, \eta = -0.54, \phi = -2.05$ jet 3: $p_T = 48 \text{ GeV}, \eta = -0.72, \phi = -1.58$



Run: 313100 Event: 231409476 2016-11-18 23:34:46 CEST

high-p_T photon p+Pb event

Prompt photon cross-section in p+Pb



- Full cross-section vs. η ($\Delta \eta \sim 4.5$) and $E_T = 20-500$ GeV
 - total uncertainties reach 2% in certain regions!
 - ➡ under-prediction of do/dE_T by JETPHOX NLO pQCD, as in pp collisions —> <u>need pp data reference</u> !

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Prompt photon R_{pPb}



Multiplicative correction for larger \sqrt{s} and center-of-mass shift of p+Pb

- construct with LO generator or NLO calculation (w/ varied PDFs)
- → resulting uncertainties are subdominant to those on σ^{p+Pb} or σ^{pp}

Use 8 TeV pp data as the reference in the photon R_{pPb}

 $R_{pPb} = \sigma^{p+Pb} / A \sigma^{pp}$

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free nucleon PDFs

global nPDF fits



- In shadowing region, data compatible with free nucleon PDFs
 - → but favors anti-shadowing in line with global nPDF fits



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Forward / backward R_{pPb} ratio vs. p_T



- $R_{pPb}^{Forward}/R_{pPb}^{Backward}$ cancel many systematic uncertainties
- At low-E_T, ratio sensitive to gluon shadowing / quark anti-shadowing
 - data almost compatible with free nucleon PDFs
 - modifications more in line with EPPS16 than nCTEQ15
- New information for global nPDF fits!

Forward dijets in *p*+Pb collisions (nucl-ex/1901.10440)



PHENIX suppression of centralforward per-trigger hadron yields STAR broadening of di-hadron away-side $\Delta \phi$ correlation

- Measure forward (2.7 < y^* < 4.0, i.e. proton-going), low- p_T (~20-40 GeV) di-jets
 - ⇒ 5.02 TeV p+Pb data 2016, paired with 5.02 TeV pp data 2015
- Measurement presented here is centrality-integrated (0-90%)



Conditional (i.e. per-trigger jet normalized) yield

$$I_{12}(p_{\mathrm{T},1}, p_{\mathrm{T},2}, y_1^*, y_2^*) = \frac{1}{N_1} \frac{d^4 N_{12}}{dy_1^* dy_2^* dp_{\mathrm{T},1} dp_{\mathrm{T},2}}$$

explored as a function of leading & subleading jet kinematics

Fix leading jet rapidity y = 2.7-4.0 (far proton-going), *scan* in subleading jet rapidity

 $I_{12}(p+Pb) < I_{12}(pp)$ for forwardforward pairs?

sub-leading jet rapidity -

Quantify p+Pb modifications via: $\rho_l = I_{12}(pPb) / I_{12}(pp)$

(cancelling common systematic uncertainties)



- No suppression for central+forward pairs
- ~20% suppression for forward-forward pairs (no significant dependence on $p_{T,1}$, $p_{T,2}$)
 - → these dijets probe $x_A \sim 10^{-4}$ to 10^{-3}
 - \Rightarrow does the suppression change the $\Delta \phi$?



nucl-ex/1901.10440

scan in sub-leading jet rapidity

Quantify p+Pb modifications via: $\rho_W = W_{12}(pPb)/W_{12}(pp)$



Quantify p+Pb modifications via: $\rho_W = W_{12}(pPb)/W_{12}(pp)$



Photon and jet probes of p+Pb collisions

New information to constrain nPDFs & *E*-loss with low-*Q*² probes sensitive to gluons, <u>nucl-ex/1903.02209</u>

Evidence of non-linear QCD effects in suppression of forward-forward dijets, <u>nucl-ex/1901.10440</u>





Prompt photon selection



Remaining background (predominantly π⁰'s in jets) removed via a double sideband procedure

Photons required to pass showershape based ID cuts, and be experimentally isolated

~90% efficiency at moderate- $E_{\rm T}$





















