Isolated photon measurements in pp and PbPb collisions with CMS

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Strong probes have surface bias

- Colored probes (dijets) occur frequently
- Dijets have two drawbacks:
  - Surface bias of data sample
  - Loss of information about initial energy
- Solution: tag strong probe (jet) with EW probe (photon)
Observables

- Azimuthal decorrelation: $\Delta \phi_{J\gamma}$, and its parametrized width $\sigma(\Delta \phi_{J\gamma})$
- Transverse momentum ratio: $x_{J\gamma} = p_{T}^{\text{Jet}} / p_{T}^{\gamma}$, and its mean $<x_{J\gamma}>$
- Fraction of photons with associated jets: $R_{j\gamma}$
- Ratio of jet yield, $\text{Jet} I_{AA}$: number of jets in each $p_{T}^{\gamma}$ and $p_{T}^{\text{Jet}}$ bin in PbPb over the number in pp.
Analysis

- Select leading isolated photon in event, correlate with all jets in event
- Apply background subtraction
  - Background from:
    - Decay/fragmentation photons ($\pi^0, \eta$)
    - Fake jets in underlying event
  - Rejected using
    - Isolation requirement (after a UE subtraction in PbPb)
    - Statistical subtraction of background photons based on purity
    - Subtraction of jets from mixed event
Background subtraction

- UE subtraction of photon isolation in PbPb
  - Isolation calculated as energy in cone of R=0.4
  - Avg. energy in area containing cone but extending to full $2\pi$ is subtracted from isolation

- Subtraction of uncorrelated jets
  - Photons correlated with jets from a different hard scattering
  - Correlation from second hard scattering subtracted

- Statistical subtraction of decay photons
  - Photon purity calculated with template method in calorimeter shower-shape variable
  - Each observable subtracted using background-enriched sample from shower-shape sideband
Kinematics

- **Photons**
  - $p_T^\gamma > 40 \text{ GeV} \ ( > 60 \text{ GeV for } p_T^\gamma \text{ inclusive plots})$
  - $|\eta^\gamma| < 1.44$
  - $p_T^\gamma$ bins: [40-50], [50-60], [60-80], [80+] GeV

- **Jets**
  - Anti-$k_T$ particle-flow jets, R=0.3, UE subtracted
  - $p_T^{Jet} > 30 \text{ GeV}$
  - $|\eta^{Jet}| < 1.6$
  - ALL jets in each event which meet criteria are included, not just leading.

- **Photon-jet pairs**
  - $\Delta\phi > 7\pi/8$
  - Centrality bins: [100-50], [50-30], [30-10], [10-0]%
Data samples and goals

- Data used in this analysis:
  - 2011 PbPb data at 2.76 TeV, 150 μb⁻¹
  - 2013 pp data at 2.76 TeV, 5.3 pb⁻¹
  - 2013 pPb data at 5.02 TeV, 30.4 nb⁻¹
- $p_{Tγ}$ dependent analysis accesses energy loss as a function of initial parton momentum
- pPb offers insight into cold nuclear matter effects
No jet deflection observed

CMS-PAS-HIN-13-006
No jet deflection observed

CMS Preliminary \[ s_{\text{NN}} = 2.76 \text{TeV}, \text{PbPb} 150 \mu \text{b}^{-1}, \text{pp} 5.3 \text{pb}^{-1} \]

$\sigma(\Delta \phi_{\gamma})$

- **PbPb Data**
- **pp Data**
- **Smeared pp reference**
- **PYTHIA + HYDJET**

- $p_T^\gamma > 60 \text{ GeV/c}$
- $|\eta^\gamma| < 1.44$
- $p_T^{\text{Jet}} > 30 \text{ GeV/c}$
- $|\eta^{\text{Jet}}| < 1.6$

CMS-PAS-HIN-13-006
Significant loss of jet partners with centrality

CMS Preliminary $|\sqrt{s_{NN}}|=2.76\text{TeV}$, PbPb 150 $\mu$b$^{-1}$, pp 5.3 pb$^{-1}$

$R_{J\gamma} = \frac{\Delta\phi_{J\gamma}}{7\pi/8}$

Fraction of photons with jet partner

$R_{J\gamma}$

$\Delta\phi_{J\gamma}$

$N_{\text{part}}$

CMS-PAS-HIN-13-006
Loss of jet partners constant over $p_T^\gamma$
Shift to lower $x_{J\gamma}$ with centrality

CMS Preliminary $\sqrt{s_{NN}}=2.76\text{TeV}$, PbPb 150 $\mu\text{b}^{-1}$, pp 5.3 pb$^{-1}$

$\Delta\phi_{J\gamma} > \frac{7}{8}\pi$

$x_{J\gamma} = \frac{p_{T}^{\text{jet}}}{p_{T}^{\gamma}}$

CMS-PAS-HIN-13-006
Shift to lower $x_{Jγ}$ with $p_T^{γ}$ in central PbPb

$$x_{Jγ} = \frac{p_T^{Jet}}{p_T^{γ}}$$
Jet spectra heavily modified

CMS-PAS-HIN-13-006

40 GeV $< p_T < 50$ GeV

50 GeV $< p_T < 60$ GeV

60 GeV $< p_T < 80$ GeV

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

PbPb 150 $\mu$b$^{-1}$

pp 5.3 pb$^{-1}$

CMS Preliminary

PbPb 0-30%

Smeared pp reference

PbPb 30-100%

Smeared pp reference

CMS Preliminary

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

PbPb 150 $\mu$b$^{-1}$

pp 5.3 pb$^{-1}$
Jet Yield shifted to lower $p_T^{Jet}$

- Jet yield pushed to lower $p_T^{Jet}$ relative to $p_T^γ$
pPb results difficult to interpret without proper reference

CMS Preliminary
\( \sqrt{s_{NN}} = 5.02 \text{ TeV} \)
pPb 30.4 nb\(^{-1}\)
pp 5.3 pb\(^{-1}\)

CMS Preliminary
\( \sqrt{s_{NN}} = 5.02 \text{ TeV} \)
pPb 30.4 nb\(^{-1}\)
pp 5.3 pb\(^{-1}\)
Conclusion

- Update of pp reference agrees with previous conclusions from PLB 718 (2013) 773:
  - No deflection of jets
  - Decrease of $x_{J\gamma}$ with centrality
  - Decrease in number of partner jets with centrality

- $p_T^{\gamma}$ – dependent results show:
  - Jet yields show a shift to lower $p_T^{Jet}$
  - Loss of jet partners roughly constant across $p_T^{\gamma}$

- pPb shows no effects; needs proper reference
Backup
Signal definition

- Signal – isolated photons
- Background – suppressed by isolation requirement