Prompt photon production with POWHEG

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Work done with T. Jezo, C. Klein-Bösing, F. König, and H. Poppenborg
References

Recent related publications:

- MK, C. Klein-Bösing, F. König, J.P. Wessels
  How robust is a thermal photon interpretation of the ALICE low-\(p_T\) data?

- M. Brandt, MK, F. König
  Nuclear parton density modifications from low-mass lepton pair production at the LHC

- MK, F. König
  New information on photon fragmentation functions

  NLO Monte Carlo predictions for heavy-quark production at the LHC: pp collisions in ALICE
Other related publications:

- R. Kunnawalkam Elayavalli, K. Zapp
  Simulating V+jet processes in heavy ion collisions with JEWEL

- J. Casalderey-Solana, D. Can Gulhan, J. Guilherme Milhano, D.
  Pablos, K. Rajagopal
  Predictions for boson-jet observables and fragmentation function
  ratios from a hybrid strong/weak coupling model for jet quenching
How robust is a thermal photon interpretation ...?


\[ \text{PbPb} \rightarrow \gamma \, X \text{ at } \sqrt{s_{NN}} = 2.76 \text{ TeV with } |y| < 0.75 \]

\[ \frac{1}{2\pi N_{ev}} \frac{dN}{d\Delta y \, dp_T} \]

- nPDF: CTEQ61 \times EPS09, FF: BFG set II
- Scaled with <T_{AA}> = 13 mb^{-1}
- ALICE 0-40% central
- \( \gamma_{\text{prompt}} = \gamma_{\text{direct}} + \gamma_{\text{fragm}} \)
- \( \gamma_{\text{direct}} \)
- \( \gamma_{\text{fragm}} \)
- \( \gamma_{\text{prompt}} \) using BFG set I
- A exp(-p_T/T) with T = 304 ± 58 MeV
New information on photon fragmentation functions


\[ \text{PDF: CT10, FF: BFG II} \]

\[ \mu_R = \mu_F = \mu_D = p_T \]

\[ \mu_R = \mu_F = p_T, \mu_D = 2 p_T \]

\[ \mu_R = \mu_F = p_T, \mu_D = 0.5 p_T \]

\[ \text{pp} \to \gamma X \text{ at } \sqrt{s} = 200 \text{ GeV with } |y| < 0.35 \]

\[ \frac{1}{2\pi\Delta y} \frac{d\sigma}{dp_T^2} \text{ (mb/GeV$^2$)} \]

CT10 with $\mu_R = \mu_F$ = 0.5 $p_T$, $\mu_D$ = 2 $p_T$

BFG set I

BFG set II

GRV

PHENIX with stat. error
Recalculation of direct processes at NLO

T. Jezo, MK, F. König, JHEP 1611 (2016) 033

Leading order:

- Tree-level processes: $q\bar{q} \rightarrow \gamma g$, $qg \rightarrow \gamma q$
- Also with color and spin correlations (needed for POWHEG)
- Traces with FormCalc 8.4, checked against literature and MG5
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- Traces with FormCalc 8.4, checked against literature and MG5

Virtual corrections:
- One-loop processes: $q\bar{q} \rightarrow \gamma g$, $qg \rightarrow \gamma q$
- Tensor reduction w/ Form, scalar functions w/ LoopTools 2.13
- Renormalization in $\overline{\text{MS}}$, checked against MG5_aMC@NLO
Recalculation of direct processes at NLO

T. Jezo, MK, F. König, JHEP 1611 (2016) 033

Leading order:
- Tree-level processes: $q\bar{q} \rightarrow \gamma g, \ qg \rightarrow \gamma q$
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Virtual corrections:
- One-loop processes: $q\bar{q} \rightarrow \gamma g, \ qg \rightarrow \gamma q$
- Tensor reduction w/ Form, scalar functions w/ LoopTools 2.13
- Renormalization in $\overline{MS}$, checked against MG5\_aMC\_aNLO

Real corrections:
- Tree-level processes: $q\bar{q} \rightarrow \gamma gg(\gamma q), \ qg \rightarrow \gamma qg, \ gg \rightarrow \gamma q\bar{q}$
- Traces with FormCalc 8.4, checked against MG5
- Dipole subtraction, QCD checked against AutoDipole 1.2.3
- Integrated QED dipole reproduces fragmentation function
Reference calculation and choice of input parameters


- JETPHOX
- Direct and fragmentation contributions
Reference calculation and choice of input parameters

NLO calculation:

- JETPHOX
- Direct and fragmentation contributions

Renormalization and factorization scales:

- $\mu = \mu_p = \mu_\gamma = p_T^\gamma$
- Variations by relative factors of two, but not four

Reference calculation and choice of input parameters

NLO calculation:  
- JETPHOX  
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- $\mu = \mu_p = \mu_\gamma = p_T^\gamma$  
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Parton densities in the proton:  
- CT10nlo

Reference and choice of input parameters:

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Parton densities in the proton:  
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Photon fragmentation function:  
- BFG set II

Reference calculations and choice of input parameters:

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- Parton densities in the proton:
  

- Photon fragmentation function:
  
The POWHEG method


NLO calculations:

• Increase normalization, reduce scale dependence \((\mu, \mu_p, \mu_\gamma)\)
• Include only one additional parton, no hadronization
The POWHEG method


NLO calculations:

- Increase normalization, reduce scale dependence ($\mu, \mu_p, \mu_\gamma$)
- Include only one additional parton, no hadronization

Parton shower Monte Carlos:

- Leading-order normalization, large scale dependence
- Many additional partons, different hadronization models
The POWHEG method


NLO calculations:
- Increase normalization, reduce scale dependence ($\mu, \mu_P, \mu_\gamma$)
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NLO+PS with POWHEG:
- Generate hardest radiation first, only positive weights
- Match to any PS (PYTHIA, HERWIG, ...) with $p_T$ veto
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- Generate hardest radiation first, only positive weights
- Match to any PS (PYTHIA, HERWIG, ...) with \(p_T\) veto

Required ingredients:
- Color- and spin-correlated squared Born amplitudes
- Finite (UV-renormalized and IR-subtracted) loop amplitudes
- Real emission squared amplitudes
Specific issues for photons

T. Jezo, MK, F. König, JHEP 1611 (2016) 033


- QED parton shower \( (q \to q\gamma) \), matched to NLO direct cont.
- Suppressed wrt. to QCD by \( \alpha / \alpha_s \), color factors, multiplicities
- Globally only 2% photons in total QCD+QED event samples
- Reweight QED radiation by \( C=50\,(100) \), check independence
Specific issues for photons

T. Jezo, MK, F. König, JHEP 1611 (2016) 033


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Renormalization and factorization scales:
- \(\mu = \mu_p = p_T^{\gamma,q,g}\) (from underlying Born process)
Specific issues for photons

T. Jezo, MK, F. König, JHEP 1611 (2016) 033

“Fragmentation” contribution:  

- QED parton shower ($q \to q\gamma$), matched to NLO direct cont.
- Suppressed wrt. to QCD by $\alpha/\alpha_s$, color factors, multiplicities
- Globally only 2% photons in total QCD+QED event samples
- Reweight QED radiation by $C=50\,(100)$, check independence

Renormalization and factorization scales:

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Parton densities in the proton:  

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T. Jezo, MK, F. König, JHEP 1611 (2016) 033


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Symmetrization of parton splitting in the final state:

- doublefsr=1
- Reduces POWHEG cross section by 10%
Photon fragmentation function in 2- and 3-jet events

S. Höche et al., Phys. Rev. D 81 (2010) 034026 (Fig. 1)

Excellent description of ALEPH data

Works also for other jet resolution parameters $y_{\text{cut}} \geq \min \left( \frac{E_i}{E_j}, \frac{E_j}{E_i} \right) \cdot \frac{s_{ij}}{s}$
Born suppression factor


Born-level event generation cut:

- $pp \rightarrow \gamma + X$ has coll. divergence at LO $\rightarrow$ impose $p_T > p_T^{\text{min}}$
- Influences events at low $p_T \rightarrow$ region of interest for thermal $\gamma$
- Not applicable for studies of QGP
Born suppression factor


Born-level event generation cut:
- \( pp \rightarrow \gamma + X \) has coll. divergence at LO \( \rightarrow \) impose \( p_T > p_T^{\text{min}} \)
- Influences events at low \( p_T \rightarrow \) region of interest for thermal \( \gamma \)
- Not applicable for studies of QGP

Analytic Born suppression factor:
- Multiplies Born cross section
  - POWHEG \( (p_{T,\text{peak}} = 10 \text{ GeV}, \text{power } i = 3) \):

\[
 f_{\text{sup.}} = \left( \frac{p_T^2}{p_T^2 + p_{T,\text{peak}}^2} \right)^i
\]

- Approximation of \( \Theta(p_T - p_T^{\text{min}}) \) (e.g. with \( p_T^{\text{min}} = 1 \text{ GeV} \)):

\[
 f_{\text{sup.}} = \frac{1}{\pi} \left[ \arctan[(p_T - p_T^{\text{min}}) \cdot 10^4] + \frac{\pi}{2} \right]
\]
- Events then reweighted by \( 1/f_{\text{sup.}} \), checked independence
Experimental conditions at RHIC

PHENIX Collaboration at RHIC

Center-of-mass energy: $\sqrt{s_{pp}} = 200$ GeV
Experimental conditions at RHIC

PHENIX Collaboration at RHIC

Center-of-mass energy: $\sqrt{s}_{pp} = 200$ GeV

- $\mathcal{L}$ (Run 2006) = 4.0 and 8.0 pb$^{-1}$
- $p_T^\gamma \in [1; 5]$ and [5; 25] GeV
- $|\eta^\gamma| < 0.35$
Experimental conditions at RHIC

PHENIX Collaboration at RHIC

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- $\mathcal{L} \ (\text{Run 2006}) = 4.0 \text{ and } 8.0 \text{ pb}^{-1}$
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- $|\eta^\gamma| < 0.35$


- $E_{\text{had.}}/E^\gamma \leq 0.1$
- $R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2} \leq 0.5$
Experimental conditions at RHIC

PHENIX Collaboration at RHIC

Center-of-mass energy: $\sqrt{s}_{pp} = 200$ GeV

Inclusive photons:
- $\mathcal{L} \text{ (Run 2006)} = 4.0$ and $8.0$ pb$^{-1}$
- $p_T^\gamma \in [1; 5]$ and $[5; 25]$ GeV
- $|\eta^\gamma| < 0.35$

Isolated photons:
- $E_{\text{had.}} / E^\gamma \leq 0.1$
- $R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2} \leq 0.5$

Photons + jets:
- $\mathcal{L} \text{ (Runs 2005 + 2006)} = 3.0 + 10.7$ pb$^{-1}$
- Anti-$k_T$ cluster algorithm with $R = 0.4$
Comparison of NLO and POWHEG with PHENIX data

T. Jezo, MK, F. König, JHEP 1611 (2016) 033

$p p \rightarrow \gamma + X$ at $\sqrt{s} = 200$ GeV

JETPHOX ($\mu = \mu_p = \mu_\gamma = p_T$) too large at low $p_T \rightarrow$ fragmentation cont.

JETPHOX ($\mu = \mu_p = 0.5 p_T, \mu_\gamma = 2 p_T$) better

[MK, F. König, EPJC 74 (2014) 3009]
Fraction of isolated photons at NLO
PHENIX Coll., Phys. Rev. D 86 (2012) 072008 (Fig. 13)

NLO too high at small and intermediate $p_T$ for all scale choices
Fraction of isolated photons with POWHEG

T. Jezo, MK, F. König, JHEP 1611 (2016) 033

\[ p p \rightarrow \gamma + X \text{ at } \sqrt{s} = 200 \text{ GeV} \]

POWHEG gives first correct description
Scale uncertainty cancels completely (no fragmentation cont.)
Transverse momentum balance of photons and jets

T. Jezo, MK, F. König, JHEP 1611 (2016) 033

\[ p \ p \rightarrow \gamma + X \text{ at } \sqrt{s} = 200 \text{ GeV} \]

\[
\frac{1}{2 \pi} \frac{d \sigma}{p_T^\gamma \ d p_T^j} \]

- **POWHEG+PYTHIA**
- **PYTHIA LO**
- **CT10nlo**
  \[ |\eta^\gamma| < 0.35 \]

Individual cuts on \( p_T^\gamma > 1 \text{ GeV} \) and \( p_T^j > 1 \text{ GeV} \)

At \( p_T^\gamma \rightarrow 0 \) NLO diverges, PYTHIA/POWHEG have finite turnover

PYTHIA underestimates absolute cross section in particular at low \( p_T \)
Azimuthal correlation of photons and jets

T. Jezo, MK, F. König, JHEP 1611 (2016) 033

\[ p p \to \gamma + X \text{ at } \sqrt{s} = 200 \text{ GeV} \]

At \( \Delta \phi \to \{0, \pi\} \) NLO diverges, PYTHIA/POWHEG have finite turnover
PYTHIA has no “fragmentation” and wrong normalization (not shown)
Contributions of isolated and “fragmentation” photons

T. Jezo, MK, F. König, JHEP 1611 (2016) 033

\[ p p \rightarrow \gamma + X \text{ at } \sqrt{s} = 200 \text{ GeV} \]

“Fragmentation” processes mostly collinear (\( \Delta \phi \simeq 0 \), but also \( \pi \))
Experimental conditions at LHC


Proton-proton collisions:

- $\sqrt{s_{pp}} = 13$ TeV
- $\mathcal{L}$ (Run 2015) = 3.2 fb$^{-1}$
Experimental conditions at LHC


Proton-proton collisions:

- $\sqrt{s_{pp}} = 13$ TeV
- $\mathcal{L}$ (Run 2015) = 3.2 fb$^{-1}$

Isolated photons:

- $\ln R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2} = 0.4$, $E_{T}^{\text{iso}} \leq 4.8 + 4.2 \cdot 10^{-3} \cdot E_{T}^{\gamma}$
- $p_{T}^{\gamma} > 125$ GeV and $|\eta^{\gamma}| < 0.6$ up to $1.81 < |\eta^{\gamma}| < 2.37$
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- \( p_{T}^{\gamma} > 125 \) GeV and \( |\eta^{\gamma}| < 0.6 \) up to \( 1.81 < |\eta^{\gamma}| < 2.37 \)

Choice of scales and PDFs:
- \( \mu = \mu_{f} = p_{T}^{\gamma} \), variations by relative factors of two (not four)
- No variations of \( Q_{0} \) for QED final state shower and \( \mu_{\gamma} \)
- NNPDF2.3QED LO/NLO (cf. Monash 2013, similar to CT14)
Sensitivity to QED shower cutoff scale $Q_0$

MK, C. Klein-Bösing, H. Poppenborg, to be published

PYTHIA 8 LO very sensitive to infrared cutoff $Q_0$ at low $p_T^\gamma$

POWHEG NLO has cancellation of virtual and soft divergences
Transverse momentum of isolated photons with ATLAS

MK, C. Klein-Bösing, H. Poppenborg, to be published

Inclusive photons $\rightarrow$ no significant differences
PYTHIA 8 LO + PS is tuned (Monash 2013) $\rightarrow$ large uncertainties
Experimental conditions at LHC (2)

CMS Coll., CMS PAS HIN-13-006

Proton-proton and proton-lead collisions:

- $\sqrt{s_{pp}} = 2.76$ TeV, $\mathcal{L}$ (Run 2013) = 5.3 pb$^{-1}$
- $\sqrt{s_{pPb}} = 5.02$ TeV, $\mathcal{L}$ (Run 2013) = 30.4 nb$^{-1}$
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- $\sqrt{s_{pPb}} = 5.02$ TeV, $\mathcal{L}$ (Run 2013) = 30.4 nb$^{-1}$

Isolated photons:

- $\ln R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2} = 0.4$, $E_T^{\text{iso}} \leq 5$ GeV
- No photons with $|\eta^\gamma - \eta^{\text{track}}| < 0.02$, $|\phi^\gamma - \phi^{\text{track}}| < 0.15$
- $p_T^\gamma > 40$ GeV and $|\eta^\gamma| < 1.44$
Experimental conditions at LHC (2)

CMS Coll., CMS PAS HIN-13-006

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- $\sqrt{s_{pp}} = 2.76$ TeV, $\mathcal{L}$ (Run 2013) = 5.3 pb$^{-1}$
- $\sqrt{s_{pPb}} = 5.02$ TeV, $\mathcal{L}$ (Run 2013) = 30.4 nb$^{-1}$

Isolated photons:
- $\text{In } R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2} = 0.4$, $E_T^\text{iso} \leq 5$ GeV
- No photons with $|\eta^\gamma - \eta^{\text{track}}| < 0.02$, $|\phi^\gamma - \phi^{\text{track}}| < 0.15$
- $p_T^\gamma > 40$ GeV and $|\eta^\gamma| < 1.44$

Jets:
- Anti-$k_T$ cluster algorithm with $R = 0.3$
- $p_T^{\text{jet}} > 30$ GeV and $|\eta^{\text{jet}}| < 1.6$
Proton-proton and proton-lead collisions:

- $\sqrt{s_{pp}} = 2.76$ TeV, $\mathcal{L}$ (Run 2013) = 5.3 pb$^{-1}$
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Jets:

- Anti-$k_T$ cluster algorithm with $R = 0.3$
- $p_T^{\text{jet}} > 30$ GeV and $|\eta^{\text{jet}}| < 1.6$

Choice of PDFs:

- CTEQ 6.1 $\overline{\text{MS}}$ (p) and nCTEQ15-np (Pb, no pion data)
Transverse momentum ratio of jets over photons with CMS

MK, C. Klein-Bösing, H. Poppenborg, to be published

No significant cold nuclear effects, softer (and more) jets at large $p_T^\gamma$
POWHEG peak sharper/at higher $x_{J\gamma}$ than PYTHIA $\rightarrow$ CMS resolution?
Mean jet transverse momentum fraction with CMS

MK, C. Klein-Bösing, H. Poppenborg, to be published

**Mean jet transverse momentum fraction**

![Graph showing mean jet transverse momentum fraction](image)

- CMS pp 2.76 TeV
- CMS pPb 5.02 TeV
- POWHEG+PYTHIA 2.76 TeV
- POWHEG+PYTHIA 5.02 TeV
- PYTHIA+HIJING 5.02 TeV

higher $p_T^\gamma$ → possible to produce $\geq 1$ jets (e.g. “Mercedes star”)
No Quark-Gluon-Plasma → not a sign of rescattering in the medium!
Azimuthal correlation of photons and jets with CMS

MK, C. Klein-Bösing, H. Poppenborg, to be published

Azimuthal isolated photon-jet correlations

40 GeV < \( p_\gamma^T \) < 50 GeV
CMS pp 2.76 TeV (PAS-HIN-13-006)
CMS pPb 5.02 TeV (PAS-HIN-13-006)
POWHEG+PYTHIA 2.76 TeV nCTEQ15(pp)
POWHEG+PYTHIA 5.02 TeV nCTEQ15(pPb)
PYTHIA+HIJING 5.02 TeV

\[|\eta| < 1.44\]
\[|\eta| < 1.6, \ |p_T^\gamma| > 30 \text{ GeV}\]

Azimuthal isolated photon-jet correlations

50 GeV < \( p_\gamma^T \) < 60 GeV
CMS pp 2.76 TeV (PAS-HIN-13-006)
CMS pPb 5.02 TeV (PAS-HIN-13-006)
POWHEG+PYTHIA 2.76 TeV nCTEQ15(pp)
POWHEG+PYTHIA 5.02 TeV nCTEQ15(pPb)
PYTHIA+HIJING 5.02 TeV

\[|\eta| < 1.44\]
\[|\eta| < 1.6, \ |p_T^\gamma| > 30 \text{ GeV}\]

Azimuthal isolated photon-jet correlations

60 GeV < \( p_\gamma^T \) < 80 GeV
CMS pp 2.76 TeV (PAS-HIN-13-006)
CMS pPb 5.02 TeV (PAS-HIN-13-006)
POWHEG+PYTHIA 2.76 TeV nCTEQ15(pp)
POWHEG+PYTHIA 5.02 TeV nCTEQ15(pPb)
PYTHIA+HIJING 5.02 TeV

\[|\eta| < 1.44\]
\[|\eta| < 1.6, \ |p_T^\gamma| > 30 \text{ GeV}\]

Azimuthal isolated photon-jet correlations

80 GeV < \( p_\gamma^T \) < 100 GeV
CMS pp 2.76 TeV (PAS-HIN-13-006)
CMS pPb 5.02 TeV (PAS-HIN-13-006)
POWHEG+PYTHIA 2.76 TeV nCTEQ15(pp)
POWHEG+PYTHIA 5.02 TeV nCTEQ15(pPb)
PYTHIA+HIJING 5.02 TeV

\[|\eta| < 1.44\]
\[|\eta| < 1.6, \ |p_T^\gamma| > 30 \text{ GeV}\]

No significant cold nuclear effects, flatter distributions at large \( p_T^\gamma \)
POWHEG NLO + PYTHIA 8 PS describes data within errors
Experimental conditions at LHC (3)

ALICE Collaboration at LHC

Proton-proton collisions:

\[ \sqrt{s_{pp}} = (0.9, 2.76, 7) \text{ TeV}, \mathcal{N}(\text{Runs 2010, 2011}) = (2, 8, 9) \cdot 10^9 \]

- Baseline for thermal photons \( \rightarrow \) no isolation cut
- Dominated by decay photons (from \( \pi^0, \eta, \omega, \ldots \))
- Multiplicity and forward (normalized) rapidity distributions
Experimental conditions at LHC (3)

ALICE Collaboration at LHC

Proton-proton collisions:  
\[ \sqrt{s}_{\text{pp}} = (0.9, 2.76, 7) \text{ TeV}, N(\text{Runs 2010, 2011}) = (2, 8, 9) \cdot 10^9 \]
- Baseline for thermal photons \( \rightarrow \) \text{no isolation cut}
- Dominated by decay photons (from \( \pi^0, \eta, \omega, \ldots \))
- Multiplicity and forward (normalized) rapidity distributions

Lead-lead collisions:  
\[ \sqrt{s}_{\text{PbPb}} = 2.76 \text{ TeV}, N(\text{Run 2010}) = (13.6 + 17.7) \cdot 10^6 \]
- \( 0.9 \text{ GeV} < p_T^\gamma < 14 \text{ GeV} \) and \( |\eta^\gamma| < 0.9 \)
- Subtraction of decay photons using \( R_\gamma = \frac{\gamma_{\text{incl.}}}{\pi^0_{\text{param.}}} / \frac{\gamma_{\text{decay}}}{\pi^0_{\text{param.}}} \)
- Direct \( p_T \) spectra with 0-20%, 20-40% and 40-80% centrality
Experimental conditions at LHC (3)

ALICE Collaboration at LHC

- \( \sqrt{s_{pp}} = (0.9, 2.76, 7) \) TeV, \( \mathcal{N} \) (Runs 2010, 2011) = (2, 8, 9) \cdot 10^9
- Baseline for thermal photons \( \rightarrow \) no isolation cut
- Dominated by decay photons (from \( \pi^0, \eta, \omega, \ldots \))
- Multiplicity and forward (normalized) rapidity distributions

- \( \sqrt{s_{PbPb}} = 2.76 \) TeV, \( \mathcal{N} \) (Run 2010) = (13.6 + 17.7) \cdot 10^6
- 0.9 GeV < \( p_T^\gamma \) < 14 GeV and |\( \eta^\gamma \)| < 0.9
- Subtraction of decay photons using \( R_\gamma = \frac{\gamma_{\text{incl.}}}{\gamma_{\text{param.}}} / \frac{\gamma_{\text{decay}}}{\gamma_{\text{param.}}} \)
- Direct \( p_T \) spectra with 0-20%, 20-40% and 40-80% centrality

Proton-proton collisions: [ALICE Coll., to be published]
- \( \sqrt{s_{pp}} = 13 \) TeV, \( p_T^\gamma \) > 2 GeV and |\( \eta^\gamma \)| < 0.9
- NNPDF2.3QED LO/NLO (cf. Monash 2013, similar to CT14)
Ratio of inclusive over decay photons with ALICE

MK, C. Klein-Bösing, H. Poppenborg, to be published

pp at $\sqrt{s} = 13$ TeV: inclusive photon yield / decay photon yield

POWHEG NLO + PYTHIA 8 PS agrees with JETPHOX NLO
PYTHIA 8 LO + PS is significantly steeper
Conclusion

Motivation:

• Prompt photons are an important probe of the QGP
• Photon-jet correlations important for jet quenching
Conclusion

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- Prompt photons are an important probe of the QGP
- Photon-jet correlations important for jet quenching

Calculation:

- Recalculation of direct photon production at NLO
- POWHEG implementation: QED PS, Born suppression
- Experiments: PHENIX at RHIC, ATLAS/CMS/ALICE at LHC.
Conclusion

Motivation:

- Prompt photons are an important probe of the QGP
- Photon-jet correlations important for jet quenching

Calculation:

- Recalculation of direct photon production at NLO
- POWHEG implementation: QED PS, Born suppression
- Experiments: PHENIX at RHIC, ATLAS/CMS/ALICE at LHC.

Results:

- Improved agreement with $p_T$ spectrum of inclusive photons
- First correct description of isolated photon fraction
- Reliable prediction for photon-jet $p_T$-balance
- First correct description of photon-jet azimuthal correlation
- Decomposition into isolated and “fragmentation” photons
Outlook

What remains to be done:

- Application to AA collisions
- Application to forward kinematics in LHCb
- Study cold nuclear effects with nPDFs
- Implement medium effects (energy loss, hydrodynamics, ...)

Theoretical setup

RHIC results

LHC results

Conclusion