On isolated prompt photon production at NICA

VII SPD Collaboration Meeting

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Overview

Motivation

Point of interest: direct measurement of the gluon distribution in the proton; in particular, for the spin-dependent gluon density Δg of a longitudinally polarized proton.

Solution:

- Physical processes, predominantly initiated by gluons at the parton level.
- Quark-initiated subprocesses are well controlled theoretically.

Must have: measurability.

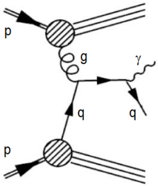
Prompt photon production

Prompt photons: all photons produced in *pp* collisions that are not secondaries from hadron decays:

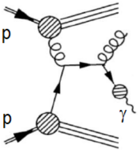
Advantages: direct processes

- $qg \to q\gamma$ provides a sensitivity already at leading order (LO) in α_s to the gluon density inside proton.
- No valence-valence scattering for $q\bar{q} \to g\gamma$ in $pp \to \gamma + X$.

Disadvantages:



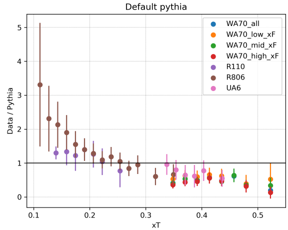
Dominant contribution

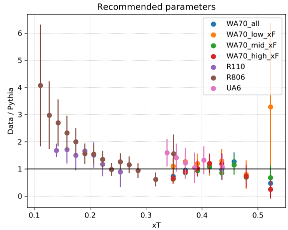


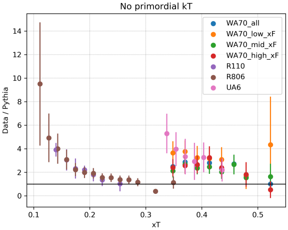
Fragmentation $D_{q\to\gamma}$

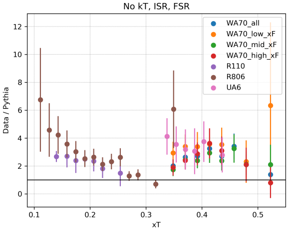
Pythia: simulation parameters

Set of experimental data: $22.96\ \text{GeV} \leq \sqrt{s} \leq 63\ \text{GeV}$









Pythia: comparison to LO analytic calculations

- **Pythia:**
  Beam remnants: primordialKT = off
  Parton level: ISR = off
  Parton level: FSR = off
  PromptPhoton: qg2qgamma = on
  PromptPhoton: qqbar2ggamma = on
  PDF:pSet = 5
- **Analytic formula:**

$$d\sigma = \int dx_1 f_a(x_1, \mu_F^2) \int dx_2 f_b(x_2, \mu_F^2) d\hat{\sigma}(ab \to \gamma d)$$

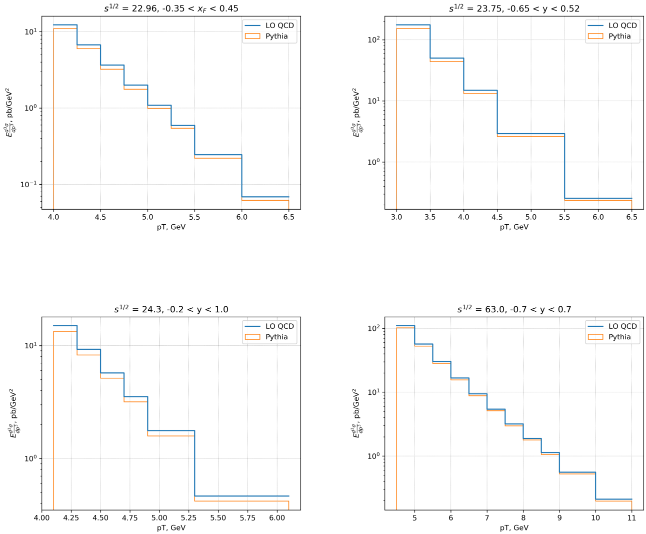
$$d\hat{\sigma} = \frac{1}{32\pi^2 I} \frac{d^3 \vec{p}_{\gamma T}}{E_\gamma} \overline{|\mathcal{M}(ab \to \gamma d)|^2}\, \delta(\hat{s} + \hat{t} + \hat{u})$$

$$p_{a,b} = x_{1(2)} P_{1(2)}; \quad P^\mu_{1,2} = \frac{1}{2}(\sqrt{s}, 0, 0, \pm\sqrt{s})$$

$$I = x_1 x_2 S; \quad a, b = q, \bar{q}(q, g); \quad q = u, d, s$$

Collinear PDFs $f_{a(b)}(x_{1,2}, \mu^2)$: MSTW 2008 LO

Pythia: comparison to LO analytic calculations



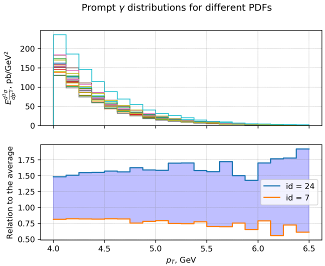
Uncertainties

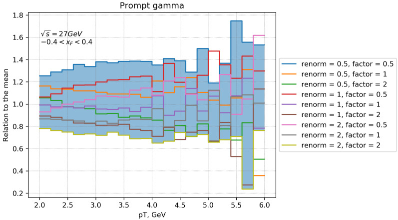
- Scale:

$$d\sigma = \int dx_1 f_a(x_1, \mu_F^2) \int dx_2 f_b(x_2, \mu_F^2) d\hat{\sigma}_{ab\to\gamma d}(\mu_R^2)$$

$$\mu_{R(F)} = r(f) p_{T,\gamma} \quad 0.5 < r, f < 2$$

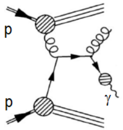
- PDF choice: NNPDF, CTEQ, MSTW, ...



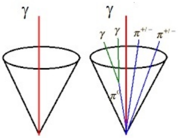


Photon isolation

Disadvantages: $D_{q\to\gamma}$



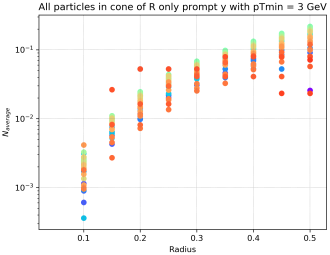
Solution: photon isolation



- Define fixed cone of radius $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$ around photon in the $\eta - \phi$ plane
- Constraint the total transverse energy inside the cone: $E_{T,tot} < E^{iso}_{T,cut} = \epsilon_\gamma E^\gamma_T$

Recent studies for $0.2 \le R \le 0.4$ at the LHC: *Becher, T., Favrod, S. and Xu, X. QCD anatomy of photon isolation. J. High Energ. Phys. 2023, 5 (2023).*

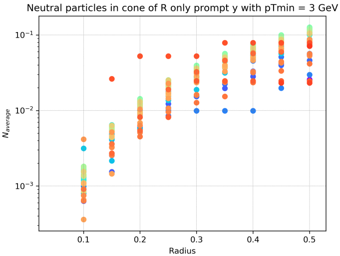
The average number of particles inside cone

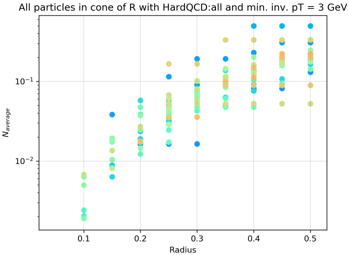


At $\sqrt{s} = 27$ GeV consider 60 intervals:

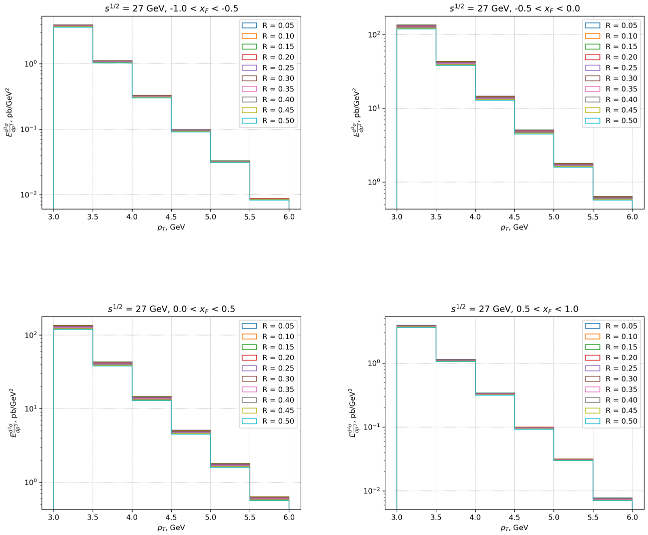
-1 $< x_F <$ 1, step 0.2;

3 GeV $< p_T <$ 6 GeV, step 0.5 GeV

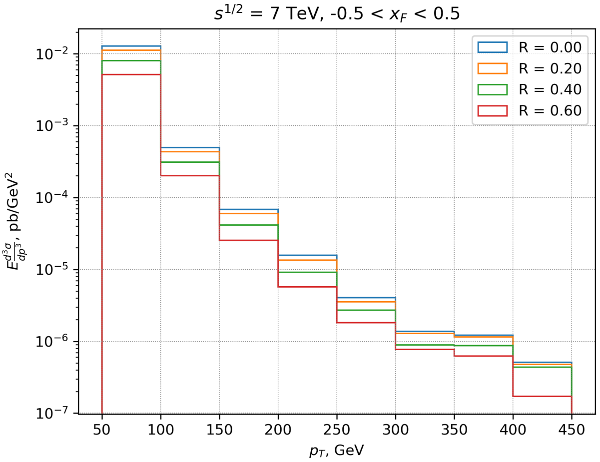




Applying the isolation cone condition



Test the isolation cone condition: LHC energies



Conclusions

Accordance

The Pythia8 simulation results and analytic calculations for the direct photon production at LO QCD reproduce each other, assuming the same choice of PDFs. This can be used for the cross-check using theoretical methods and Pythia8.

Photon isolation

The prompt photons at NICA can be treated as isolated in a good approximation, that allows to skip the fragmentation contribution and indicates a lack of double counting when considering the high-order real QCD corrections.

MC NLO

The NLO calculations for the further description with higher precision are needed: MadGraph, Sherpa, JETPHOX.

Acknowledgements

We are grateful to I. Denisenko for the help to perform the studies using Pythia8.

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Thank you for attention!