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Measurement of Direct Photon Cross Section and Double Helicity Asymmetry at $\sqrt{s} = 510$ GeV in $\vec{p} + \vec{p}$ Collisions at PHENIX

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UCLA & Stony Brook University

Quark Matter 2022

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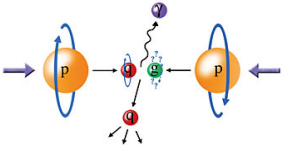
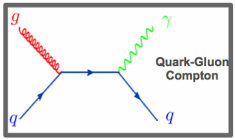
PHENIX

QM QUARK MATTER KRAKÓW 2022

Direct photon as the "golden" channel



$$A_{LL}^{pp\to\gamma X} \sim \frac{\Delta q(x_q)}{q(x_q)} \cdot \frac{\Delta g(x_g)}{g(x_g)} \cdot a_{LL}^{qg\to\gamma q}$$



- $A_{LL} = \frac{\Delta\sigma}{\sigma} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$
- Little fragmentation contributions.

- "Golden" channel.
- Linear in Δg: probe the sign of gluon spin.

Challenges in the direct photon measurement:

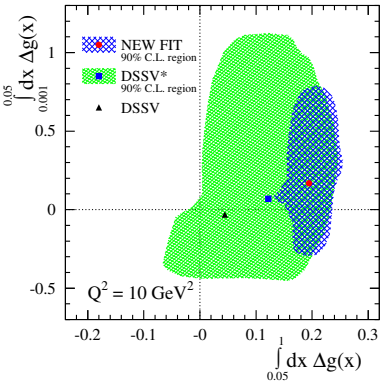
- Low statistics.
- π^0 decay photon merging at high p_T in the EMCal detector.

Advantages at PHENIX with RHIC running period of year 2013:

- The largest integrated luminosity (155 pb^{-1}) in $\vec{p} + \vec{p}$
- EMCal with fine granularity to separate π^0 decay photons up to p_T of 12 GeV/c, and a shower profile analysis extends the γ/π^0 discrimination to beyond 20 GeV/c.

From A_{LL} to Δg

- Existing RHIC data mainly probe $0.05 < x_g < 0.2$
- PHENIX π^0 A_{LL} at 510 GeV confirms a nonzero Δg and extend x_g to 0.01
- STAR jet data clearly imply a polarization of gluons in this range.
- This will be the first direct photon A_{LL} result to be published [arXiv: 2202.08158]
- Our results will add independent constraints on the Δg



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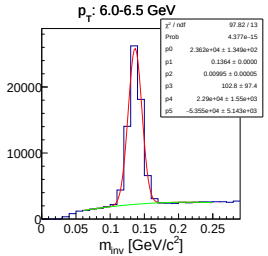
Direct photon signal extraction

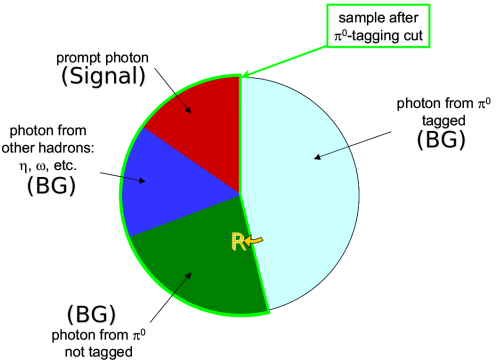
Source of direct photon:

- Compton scattering: $g + q \rightarrow \gamma + q$
- Annihilation: $q + \bar{q} \rightarrow \gamma + g$
- Parton fragmentation to photon.
- Quark bremsstrahlung.

Source of direct photon background:

- Decay photons from mesons (π^0, η, ω, η').

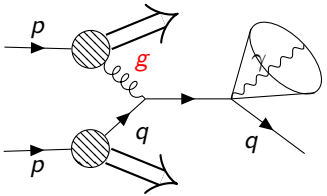




Yield of direct photon:

- $N_{dir} = N_{total} - (1 + A)(1 + R)N_{\pi^0}$
  - R: π^0 one photon missing ratio.
  - A: Other hadrons' to π^0's photon ratio.

Identifying direct photon through isolation

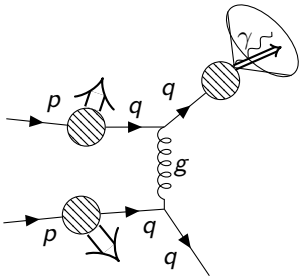


$$r_{\text{cone}} = \sqrt{(\delta\eta)^2 + (\delta\phi)^2} = 0.5$$

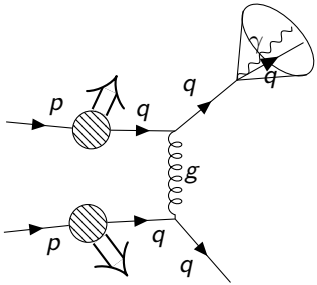
Isolation cut requirement:

$$\sum E_{\text{in cone}} < 0.1 E_{\gamma}$$

Quark-gluon Compton scattering: Easy to pass isolation cut



Fragmentation: Hard to pass isolation cut



Bremsstrahlung: Hard to pass isolation cut

Results [arXiv: 2202.08158]

- Gluon spin is important for proton spin decomposition.
- Direct photons have little fragmentation contributions.
- First direct photon xsec and A_{LL} at 510 GeV.
- Independent constraint on the gluon spin contribution.