Probing nuclear parton densities and parton energy loss processes through photon + heavy-quark jet production in p-A and A-A collisions

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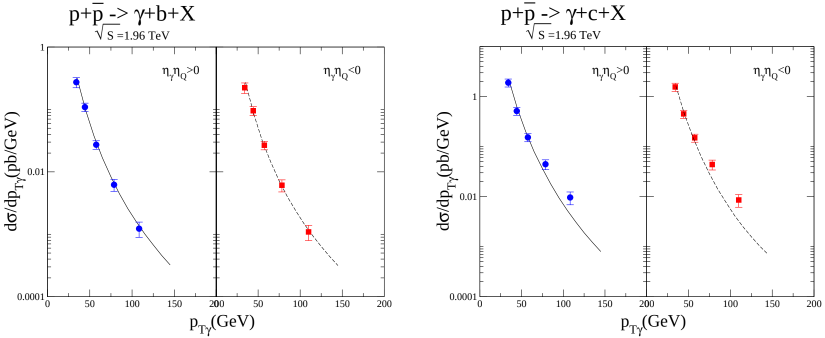
LPSC Grenoble

Prompt Photons and Heavy Quark Jets

- Prompt photons - produced in hard scattering or via fragmentation
- Heavy quark jet - charm or bottom jet
- Depending on the collision type this process can be useful in various ways
- In $p - \bar{p}$ collisions - arXiv:0901.3791, arXiv:0901.0739 - useful for testing the charm or bottom PDF (intrinsic charm or bottom)
- In $p - A$ collisions (LHC,RHIC) can be used to constrain the gluon nuclear PDF (nPDF) - (arXiv:1012.1178)
- Knowing the precise nPDFs is necessary for obtaining reliable predictions in $A - A$ collisions!
- In $A - A$ collisions - helps to obtain a better understanding of the parton energy loss processes in the massive quark sector (work in progress)

Comparison between theory and data @ $p - \bar{p}$

Measurements by DØ Collaboration

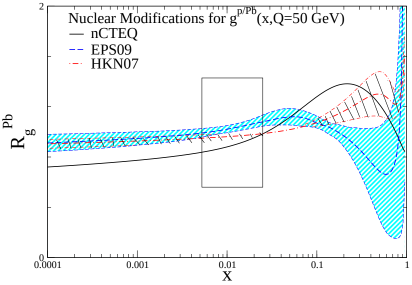


- Really good agreement between data and theory for $\gamma + b$
- For $\gamma + c$ data at large $p_{T\gamma}$ is above the theory curve $\rightarrow$ possible explanation - existence of intrinsic charm

The gluon nPDF

- Lack of data constraining the nuclear gluon PDF
- Illustrated by:

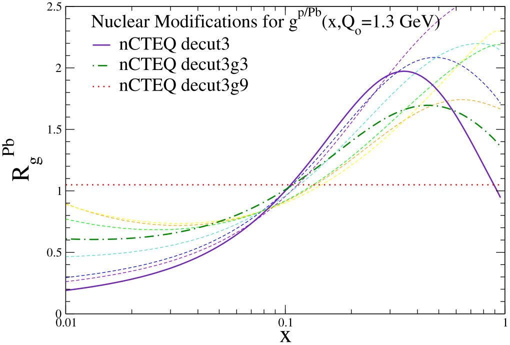
$$R_g^{Pb}(x,Q) = g^{p/Pb}(x,Q)/g^p(x,Q)$$



- Different nPDF sets (nCTEQ, EPS and HKN + errors) → differing predictions - need a more precise determination of $g^{p/Pb}(x,Q)$ ⇒ LHC data is needed!

The nCTEQ nPDFs

- Different equally good fits representing the spread in the gluon nPDF



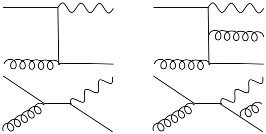
Available at: **http://projects.hepforge.org/ncteq/**

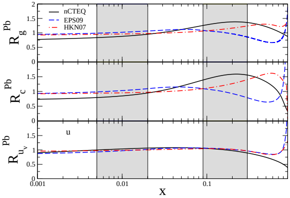
fits	decut3	nuanua1	globfac
data	charged lepton	neutrino	charged lepton + neutrino

- For more details see J.-Y. Yu's talk (21.07 15:00 Session: QCD)

How can $\gamma + Q$ help ?

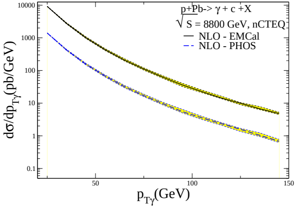
- At LO - only one hard scattering subprocess Compton subprocess - $g - Q$ initiated + fragmentation contributions
- Standard approach: HQ PDFs are generated radiatively $\Rightarrow$ $R_g^{Pb} \simeq R_c^{Pb}$

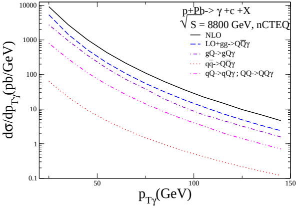




- Direct access to gluon nPDF

$\gamma + Q$ production in $p - Pb$ collisions @ the LHC

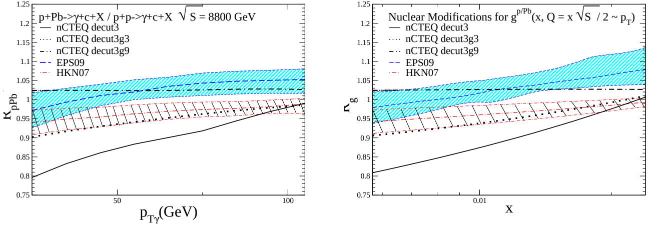




- g & Q initiated subprocesses dominate ($> 80\%$) $\Rightarrow$ sensitivity to gluon and HQ PDFs.
- Using an integrated yearly luminosity of $\mathcal{L} = 10^{-1} pb^{-1}$ a precursory number of events per year at EMCal for $\gamma + c$ is $\mathcal{N}^{pPb}_{\gamma+c} = 11900$ ($\sigma^{pPb}_{\gamma+c} = 119nb$) and for $\gamma + b$ is $\mathcal{N}^{pPb}_{\gamma+b} = 2270$ ($\sigma^{pPb}_{\gamma+b} = 22.7nb$)

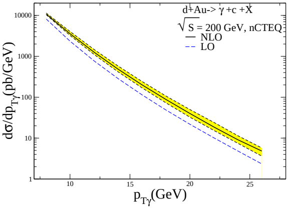
Constraining the gluon nPDF

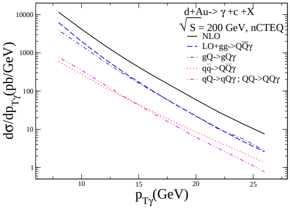
$$R_{pA}^{\gamma Q} = \frac{\sigma(pA \to \gamma\ Q\ \mathrm{X})}{A\ \sigma(pp \to \gamma\ Q\ \mathrm{X})}$$



- $R_{pA}^{\gamma Q} \simeq R_g^{Pb}$ - in the x region probed at ALICE
- Measurements of $\gamma + Q$ with appropriate error bars will allow to distinguish between the different nPDF sets and place useful constraints on the gluon nPDF (arXiv:1012.1178)

$\gamma + Q$ production in $p - Pb$ collisions @ RHIC





- g & Q initiated subprocesses dominate again $\Rightarrow$ sensitivity to gluon and HQ PDFs.
- A precursory number of events per year for $\gamma + c$ - $\mathcal{N}^{dAu}_{\gamma+c} = 28000$ and for $\gamma + b$ - $\mathcal{N}^{dAu}_{\gamma+b} = 24$

Constraining the gluon nPDF

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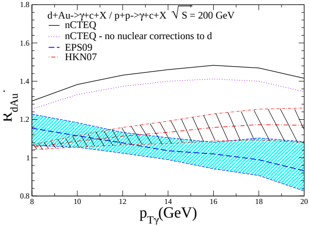

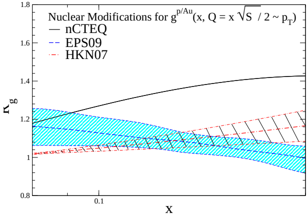

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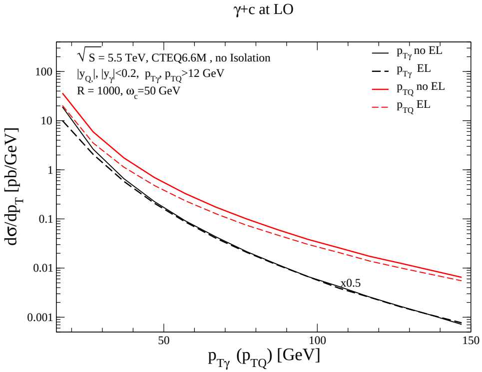
$\gamma + Q$ in $A - A$ Collisions

- Need more differential observables to quantify the amount of energy loss, e.g. $\gamma + jet$ correlations (X.-N. Wang, Z. Huang, I. Sarcevic hep-ph/9605213, F. Arleo, P. Aurenche, Z. Belghobsi, J.-P. Guillet hep-ph/041008)
- $\gamma + Q$ ideal for probing hot QCD medium
- Q - Jet Quenching
- γ is medium insensitive $\Rightarrow$ can gauge HQ's initial energy

$\gamma + Q$ in $A - A$ Collisions

- $\gamma + Q$ can help to clarify the energy loss in the heavy quark sector ($\epsilon_q > \epsilon_c > \epsilon_b$) (Heavy quark colorimetry of QCD matter -Y. L. Dokshitzer, D.E. Kharzeev)
- The two-particle final state further offers a range of observables
- ϵ_Q computed on an event by event basis, with quenching weight obtained perturbatively [Armesto Dainese Salgado Wiedemann 2005 (arXiv:hep-ph/0501225)]
- work in progress T.S., F.Arleo, I. Schienbein

Effects of energy loss on the $\gamma + Q$ cross-section - LO

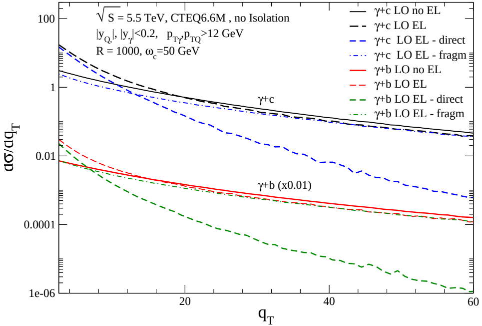


- Difference in spectrum vs p_{TQ} in vacuum and in medium $\Rightarrow$ due to energy loss
- $\frac{d\sigma}{dp_{T\gamma}}$ spectrum almost unchanged

Effects of energy loss on the $\gamma + Q$ cross-section - LO

- Photon-jet pair momentum:

$$q_\perp = |\vec{p}_{T\gamma} + \vec{p}_{TQ}|$$

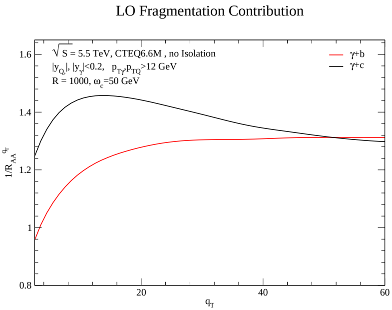


- At LO direct component - $q_\perp \simeq \epsilon_Q$
- At LO fragmentation component - ϵ_Q represents the shift of the q_T spectrum in vacuum vs the one in medium

$q_\perp$ in more detail - I

- Direct and fragmentation components behave very distinctly
- In medium the direct contribution decreases sharply with increasing q_T $\Rightarrow$ small probability of events with large ϵ_Q
- In vacuum the direct contribution is non-zero only at $q_T = 0$
- Therefore compare only the vacuum and medium fragmentation contributions

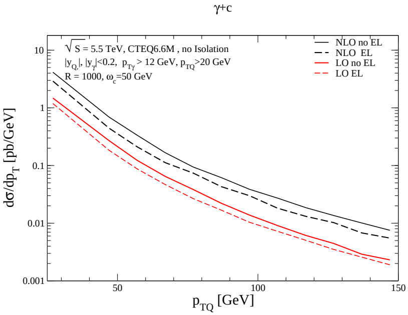
$q_\perp$ in more detail - II



- $\Delta E_c > \Delta E_b$; as q_T grows the difference disappears, as the quenching weight depends on m/E, which becomes similar for $\gamma + c$ and $\gamma + b$ at large q_T
- Need to compare σ in medium and vacuum at the NLO level, where the particles have a larger kinematic phase-space!

$\gamma + Q$ at NLO

- assume the medium induced effects factorize from hard-scattering cross-section
- preliminary NLO cross-section in medium



Conclusions

- $\gamma + Q$ **production** - versatile process
- constrain the HQ PDFs in hadron-hadron collisions
- constrains gluon nPDF in $p - A$ collisions
- In $A - A$ collisions it can be used for an estimate of the HQ energy loss + access to the mass hierarchy of parton energy loss