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Coherent Photoproduction of J/ψ and ee in Hadronic Heavy-Ion Collisions

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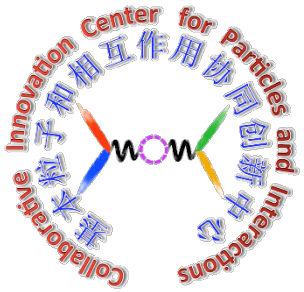


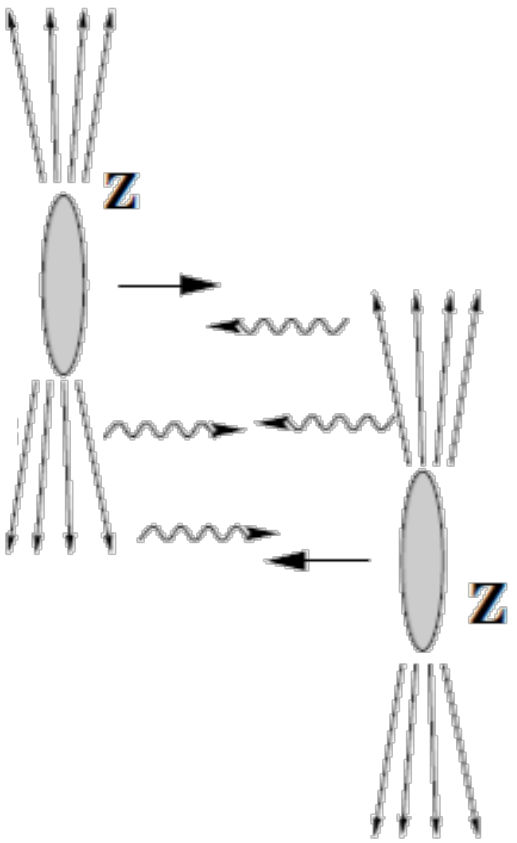
Electromagnetic Field in Heavy-Ion Collisions

- Strong EM field accompanies the nuclei in relativistic heavy-ion collisions

$$B \sim \gamma Zeb/R^3 \sim O(10^{18}\ Gauss)\ @\text{RHIC}$$

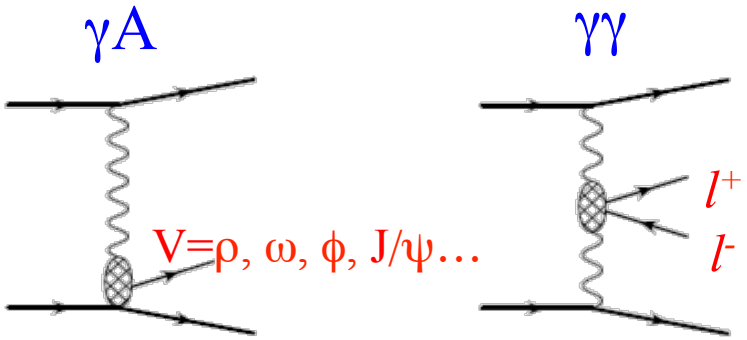
- The Lorentz contracted EM field can be expressed in terms of equivalent photon flux *E. Fermi, Z. Phys. 29, 315 (1924)*

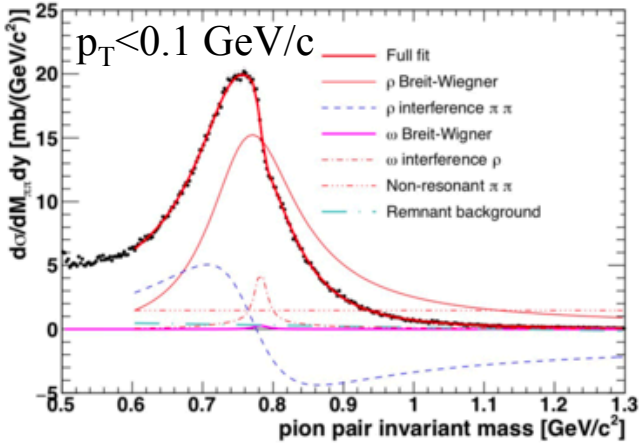
$$k_T <\sim 1/R \sim 0.03\ GeV\ @\text{RHIC/LHC}$$
$$k_0 <\sim \gamma/R \sim \quad 3 \quad GeV\ @\text{RHIC}$$
$$\quad\quad\quad\quad\quad\quad 80 \quad GeV\ @\text{LHC}$$
$$n(\vec{k}, \vec{x}_T) \propto Z^2 \alpha_{em}$$



- The quasi-real photons can initiate γA or γγ collisions in relativistic heavy-ion collisions

Coherent Photoproduction



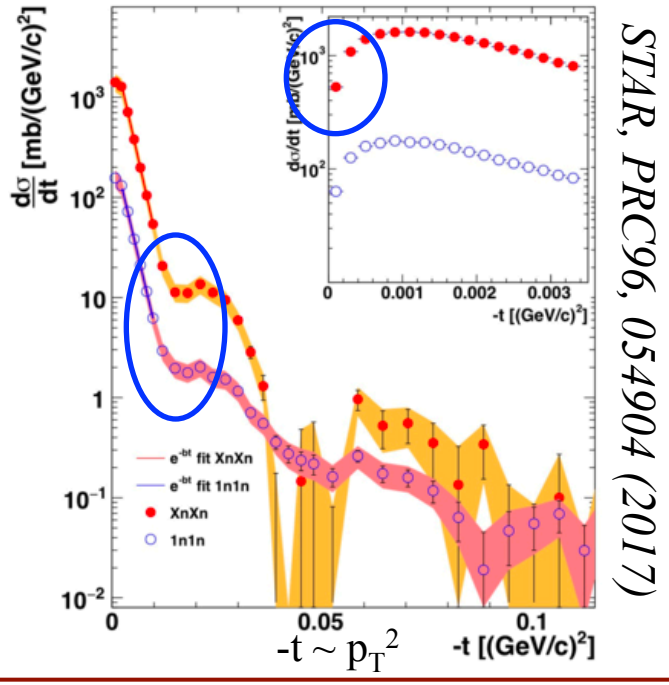


Traditionally studied in Ultra-Peripheral Collisions (UPC)

$b>R_A+R_B$

No hadronic interaction

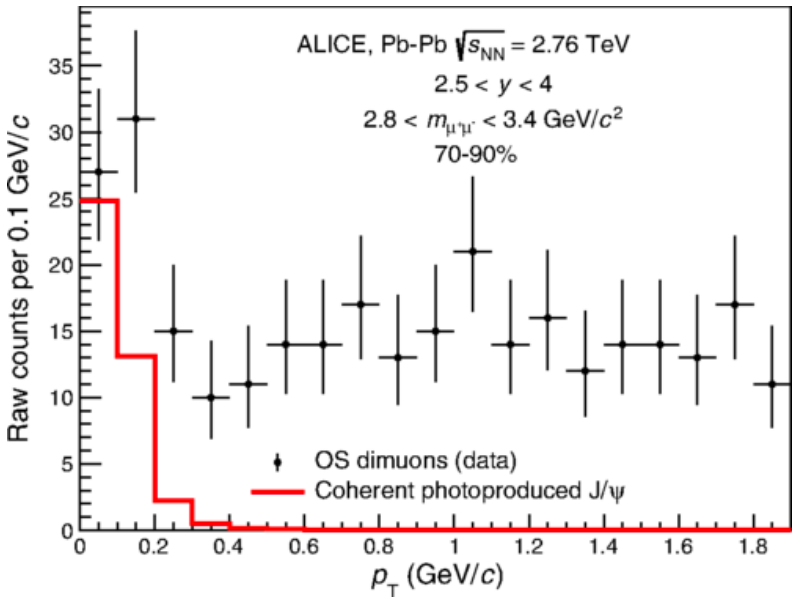
Diffractive dips and destructive interference seen in ρ photoproduction

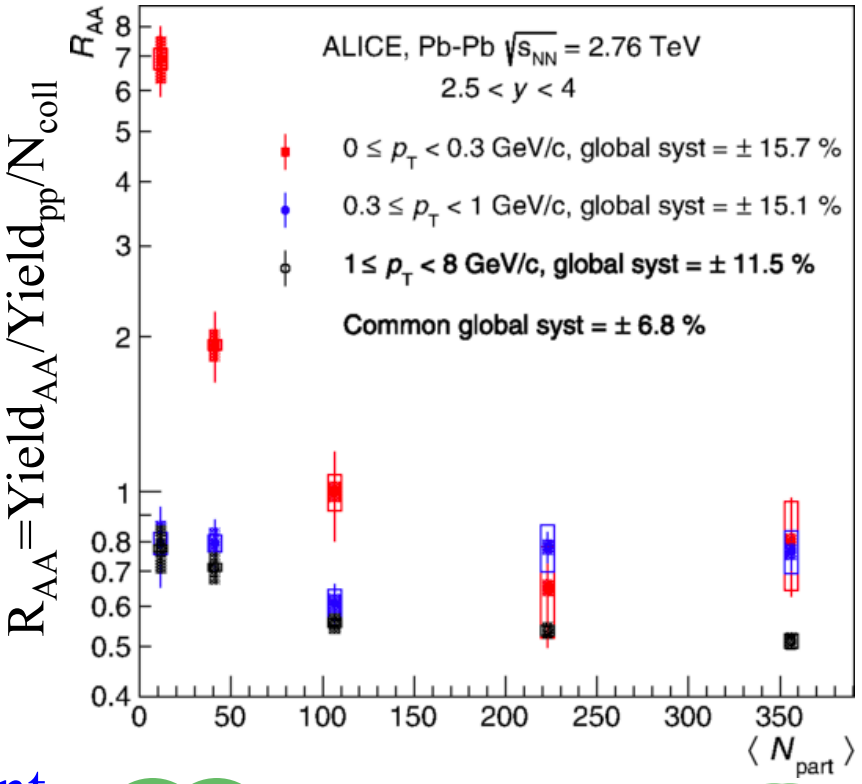


STAR, PRC96, 054904 (2017)

Very-low-p_T J/ψ Enhancement at ALICE

ALICE, PRL116, 222301 (2016)

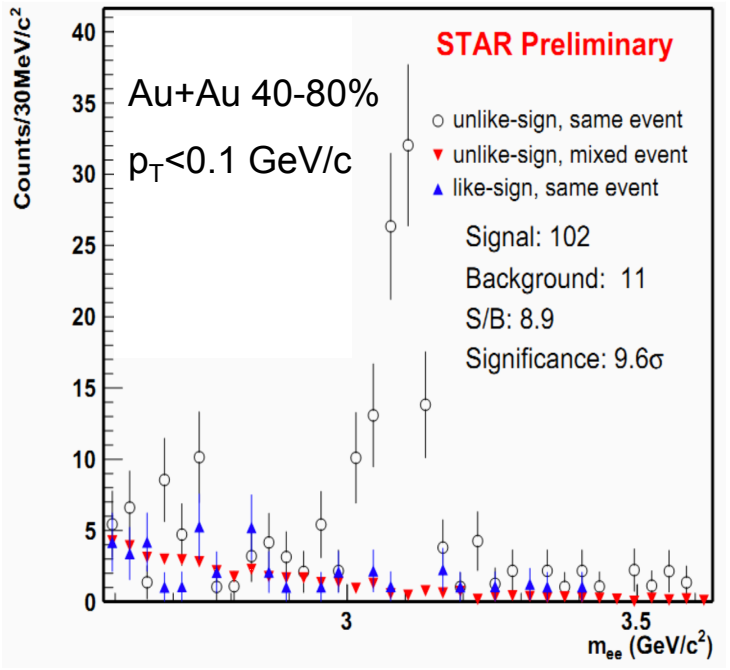


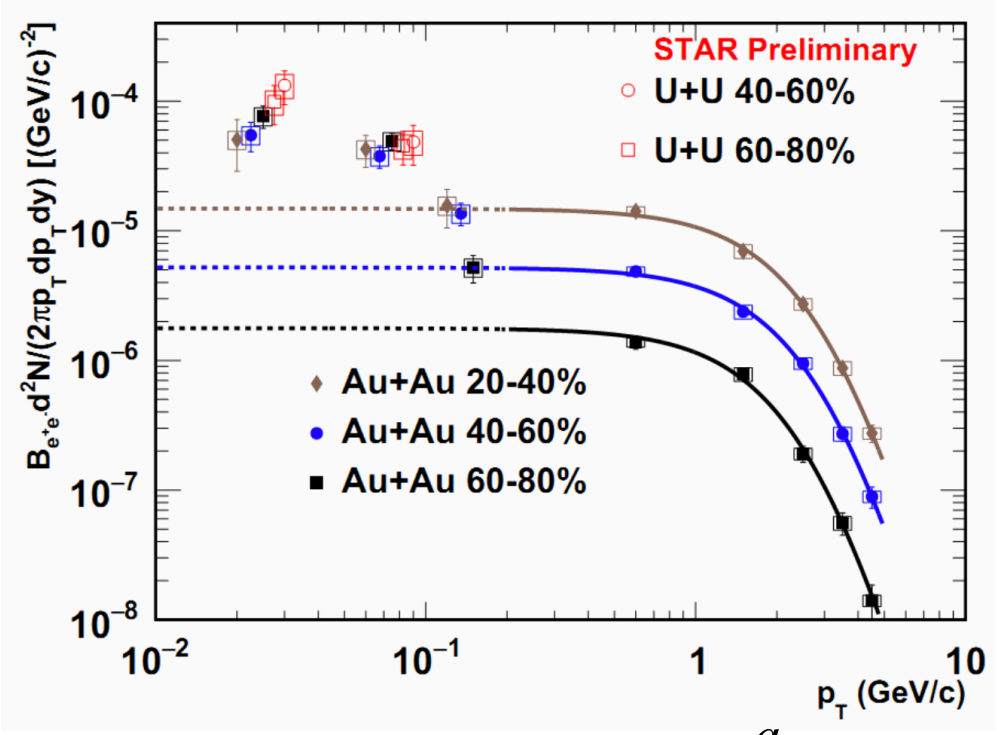


ALICE observed strong enhancement of J/ψ at very low-p_T in peri. collisions

Originate from coherent photoproduction in non-UPC?

Very-low-p_T J/ψ Enhancement at STAR



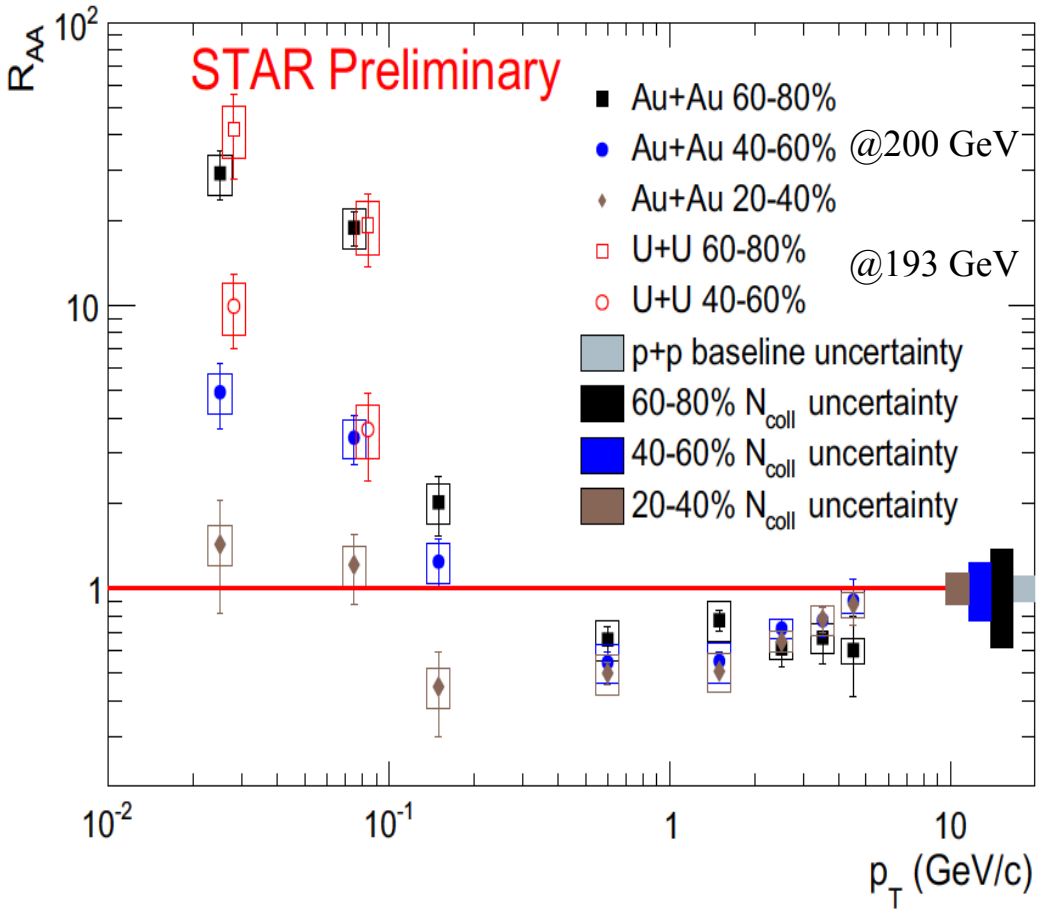


Clear signal at very low p_T

Fit fun. (empirical): $\dfrac{a}{\left(1+b^2 p_T^2\right)^n}$

Significant enhancement of J/ψ yield at p_T<0.2 GeV/c in (semi-)peripheral Au+Au and U+U collisions

$R_{AA}(p_T)$ in Au+Au and U+U Collisions



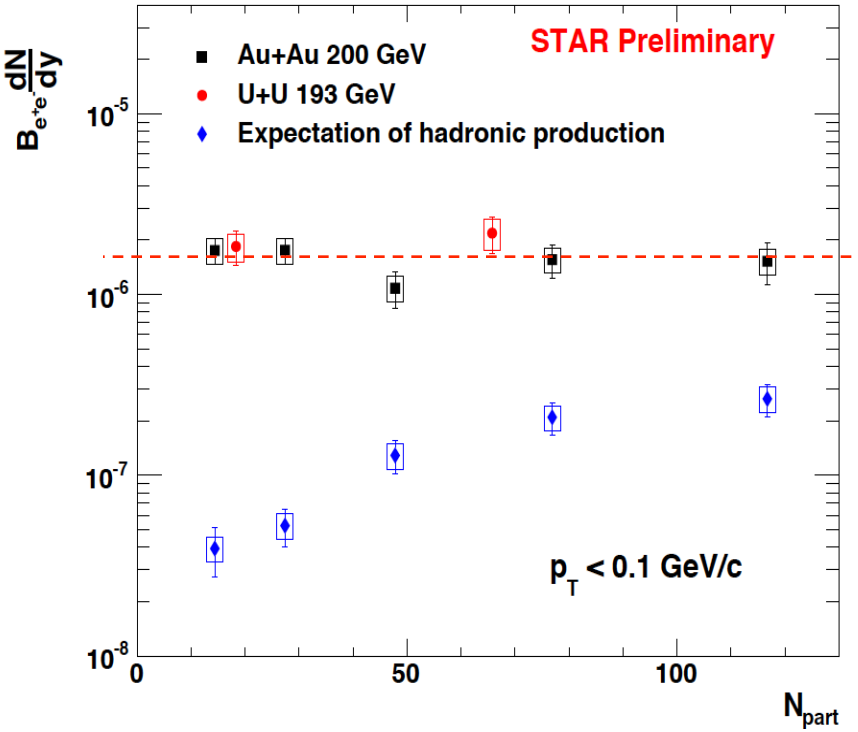
$R_{AA} \sim 30\text{-}40$

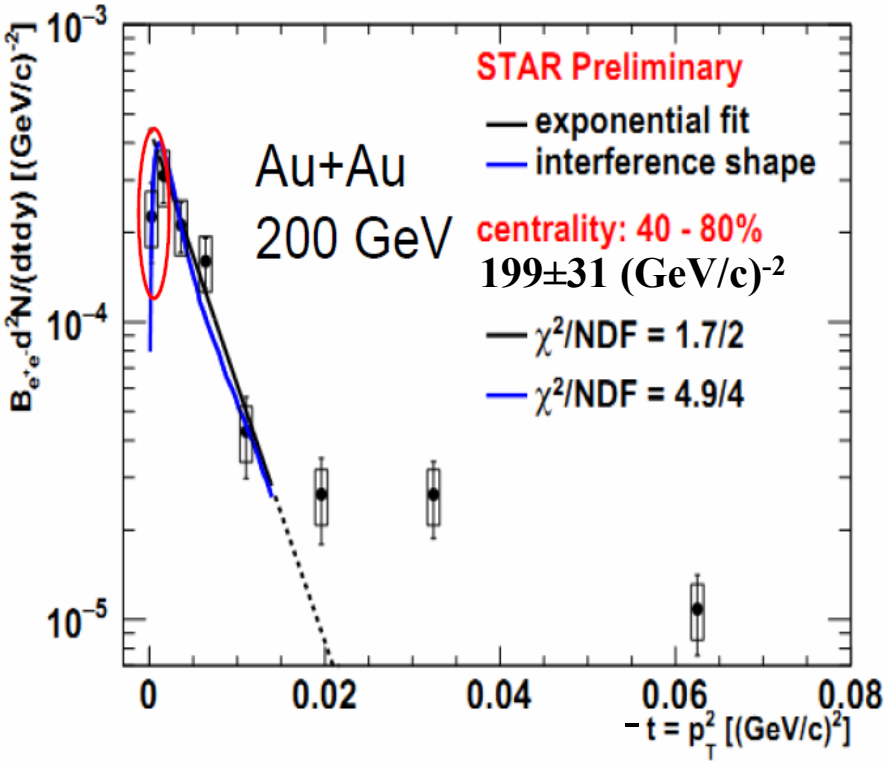
at $p_T < 0.05$ GeV/c

in 60-80% central

Au+Au and U+U

Centrality and $-t$ Dependence





Excess yield has no obvious centrality dependence

t distribution consistent with interference

slope similar to that from UPC

Modeling Coh. J/ψ Photo-prod. in Non-UPC

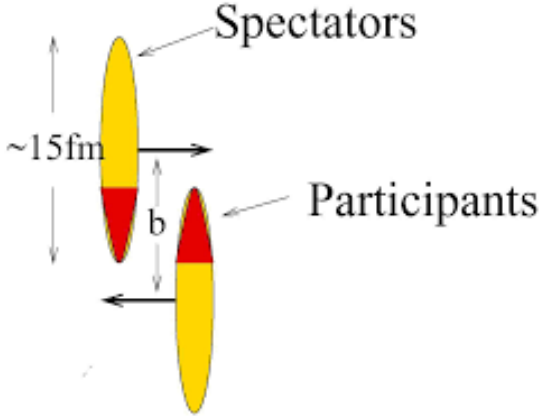
$$\sigma(AA \to AAJ/\psi) = \int d\omega_\gamma \frac{dN_\gamma(\omega_\gamma)}{d\omega_\gamma} \sigma(\gamma A \to J/\psi A)$$

Photon flux:

$$\frac{d^3N_\gamma(\omega_\gamma, \vec{x}_\perp)}{d\omega_\gamma d\vec{x}_\perp} = \frac{4Z^2\alpha}{\omega_\gamma} \left| \int \frac{d^2\vec{k}_{\gamma\perp}}{(2\pi)^2} \vec{k}_{\gamma\perp} \frac{F_\gamma(\vec{k}_\gamma)}{|\vec{k}_\gamma|^2} e^{i\vec{x}_\perp \cdot \vec{k}_{\gamma\perp}} \right|^2$$

EM form factor ← Woods-Saxon distribution

From entire nucleus or spectator?



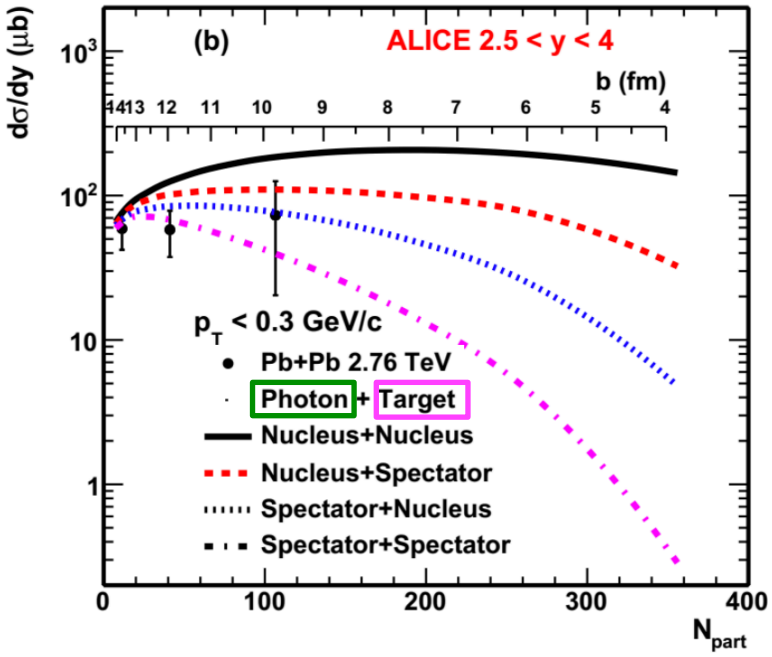
Photonuclear scattering:

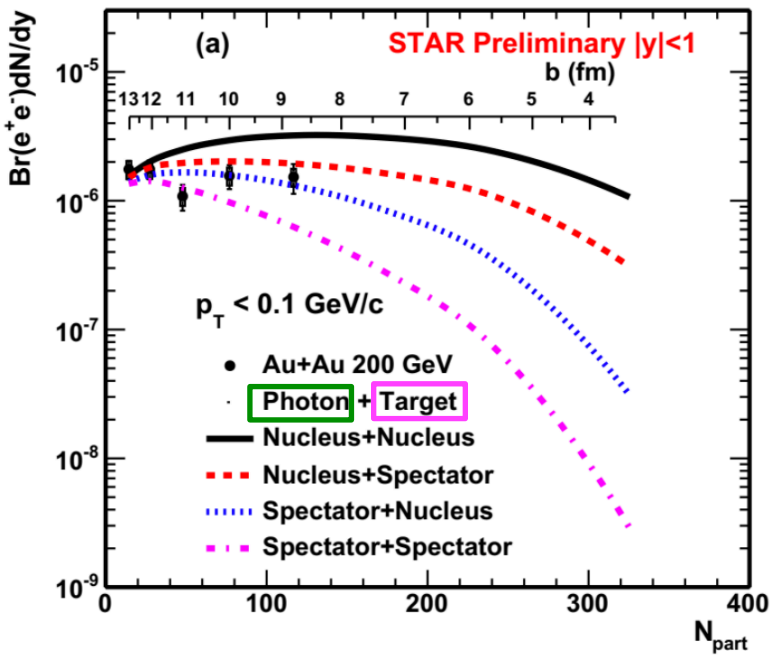
$$\sigma(\gamma A \to J/\psi A) = \left. \frac{d\sigma(\gamma A \to J/\psi A)}{dt} \right|_{t=0} \times \int |F_P(\vec{k}_P)|^2 d^2\vec{k}_{P\perp}$$

Form factor for Pomeron ← Nuclear density distribution

From entire nucleus or spectator?

Data vs. Model



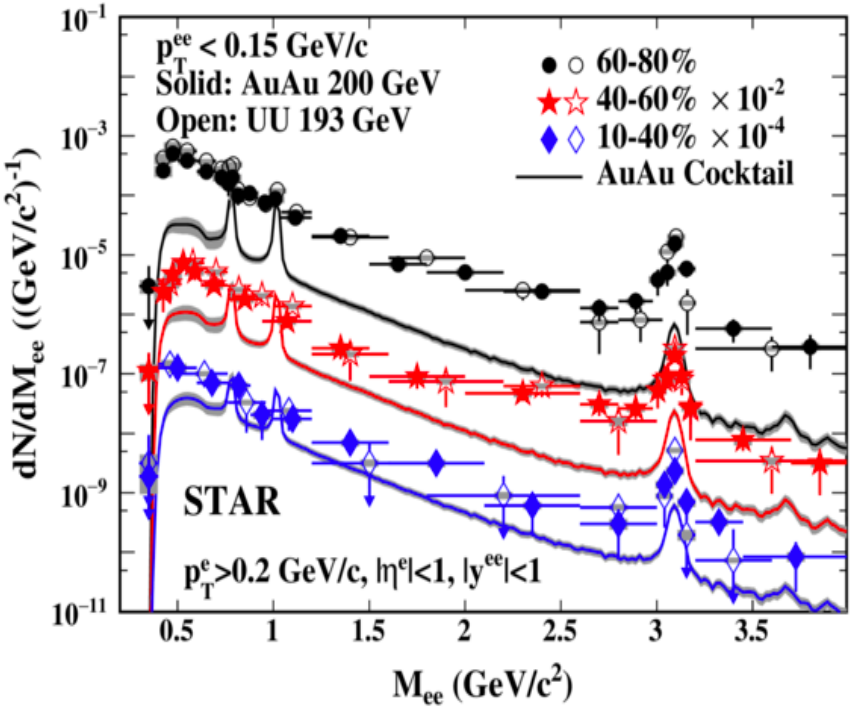


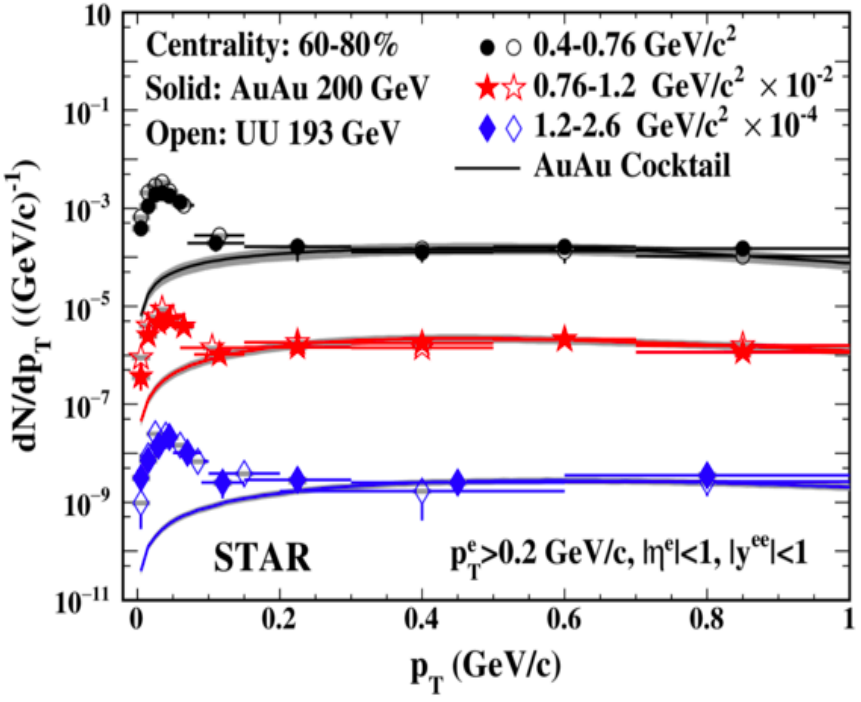
W. Zha, S. Klein, R. Ma, et. al, PRC97, 044910 (2018)

- All scenarios describe data at b~2R
- "Nucleus+Spectator" and "Spectator+Nucleus" are favored
- How to test photon emitter? γγ!

Very-low-p_T ee Enhancement at STAR

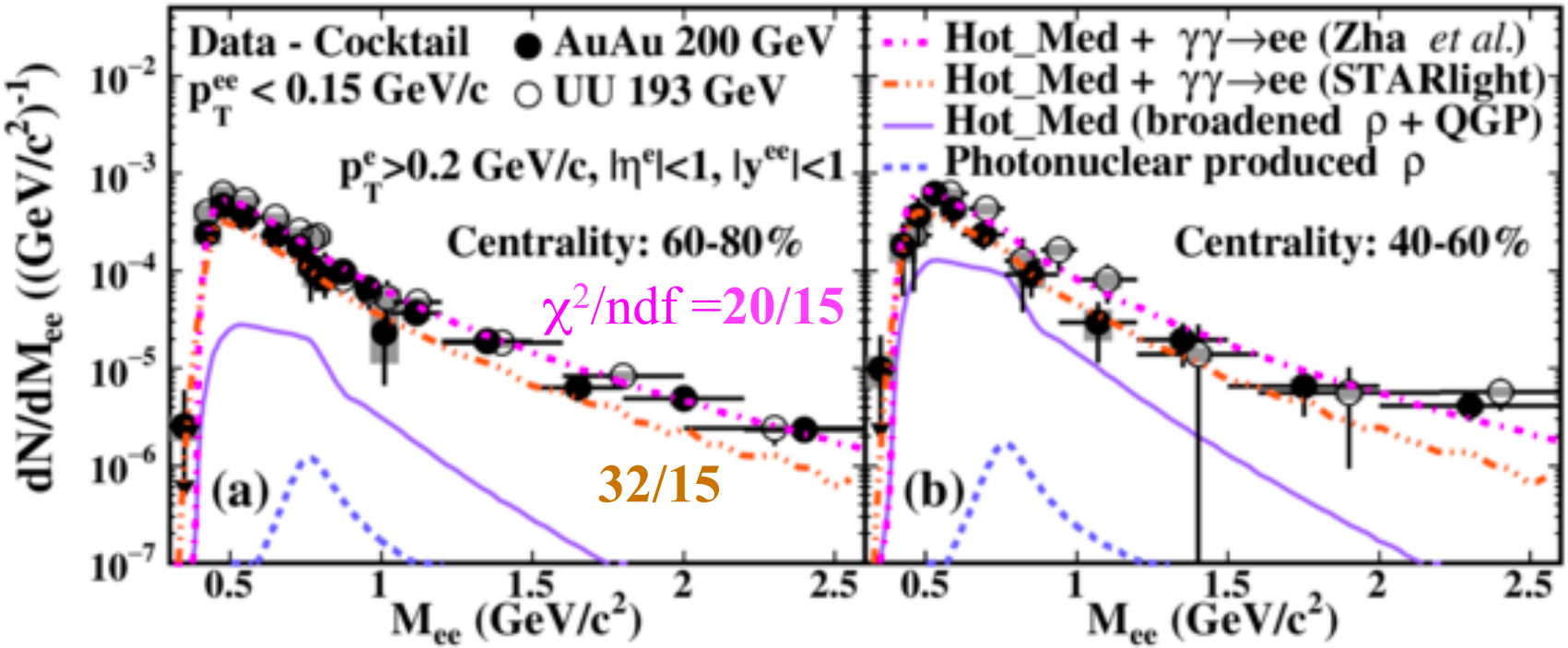
STAR, arXiv:1806.02295, submitted to PRL





Significant enhancement of dilepton yield at p_T<0.15 GeV/c in (semi-)peripheral Au+Au and U+U collisions

Data vs. Model



Very-low-p_T dilepton dominantly produced by γγ in peri. collsions

Well described by theoretical calculations

W. Zha et al, PLB 781, 182 (2018)

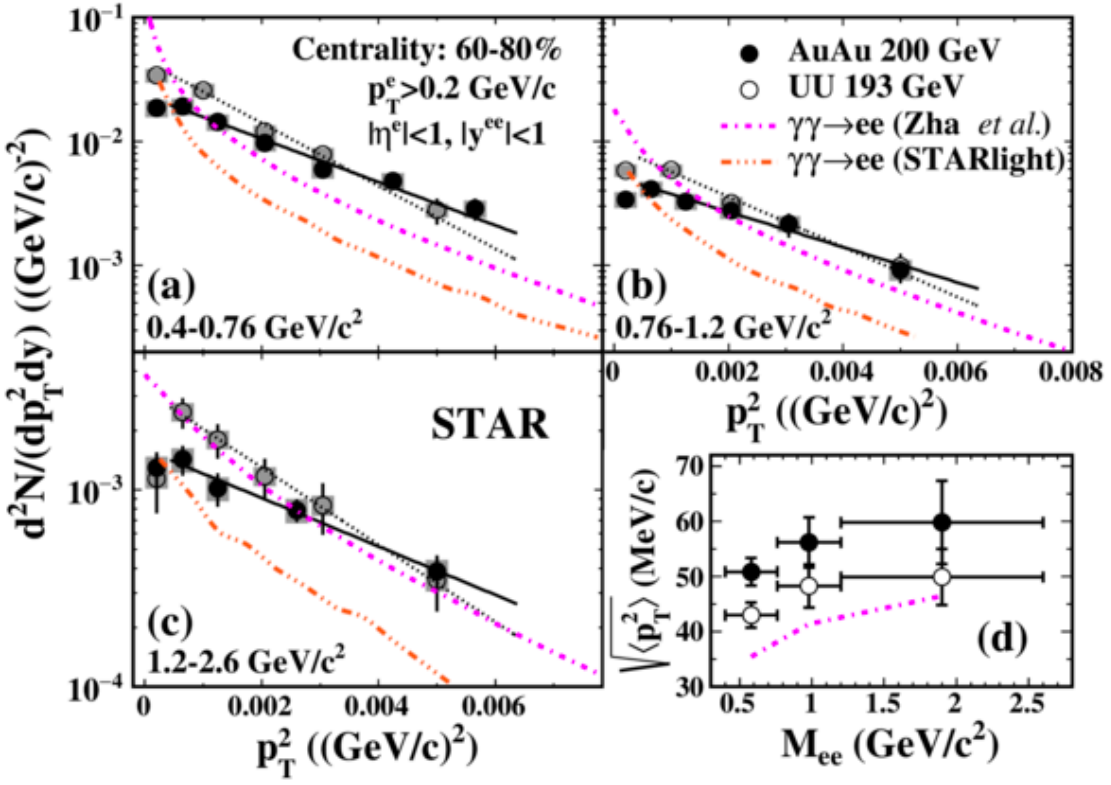
Zha et al.: Woods-Saxon, entire nucleus as emitter

STARlight: point-like charge, ignore x_T>R

S. Klein, PRC97, 054903 (2018)

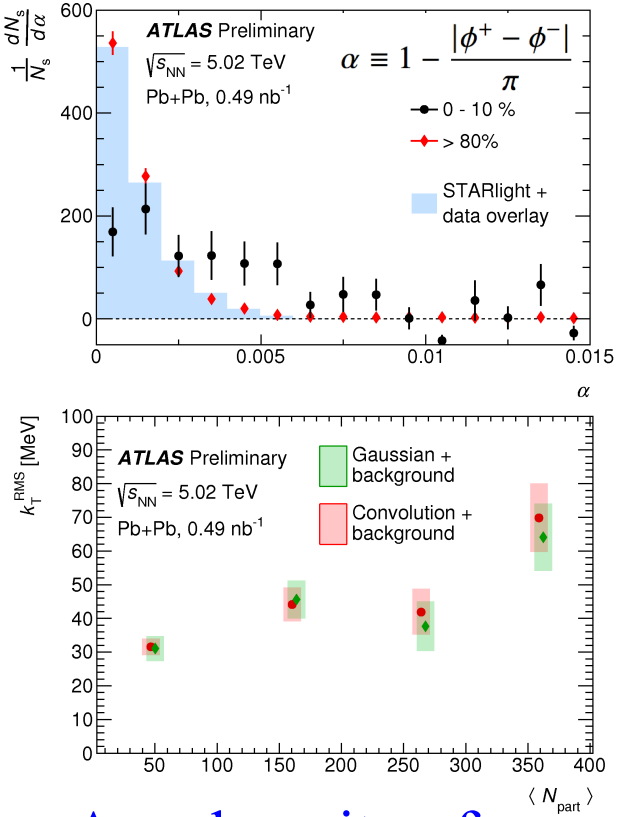
Transverse Momentum Broadening

STAR, arXiv:1806.02295, submitted to PRL



p_T^2 in data broader than in both models

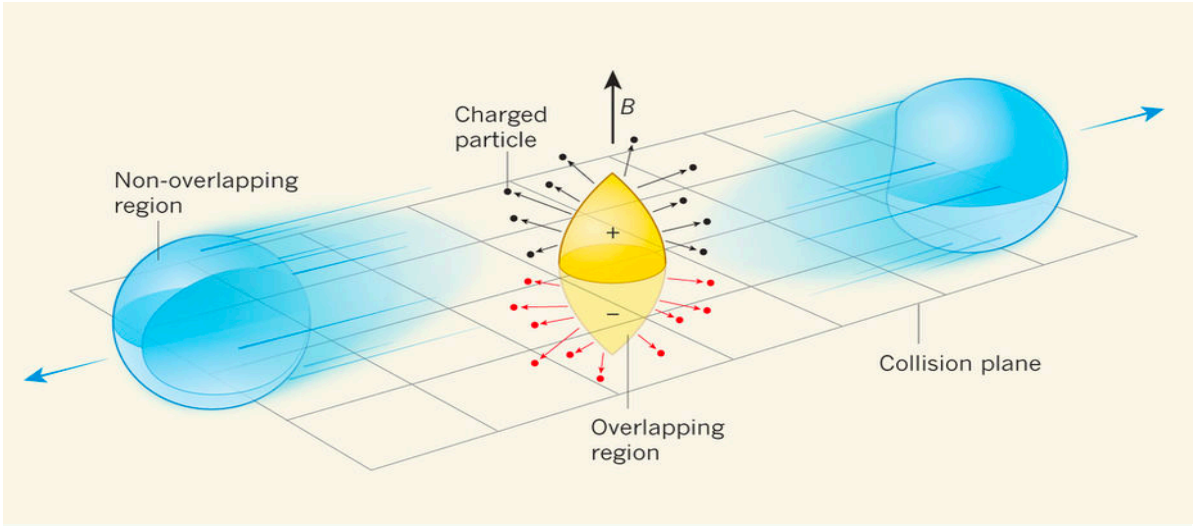
ATLAS, arXiv:1806.08708, submitted to PRL



Acoplanarity of μμ

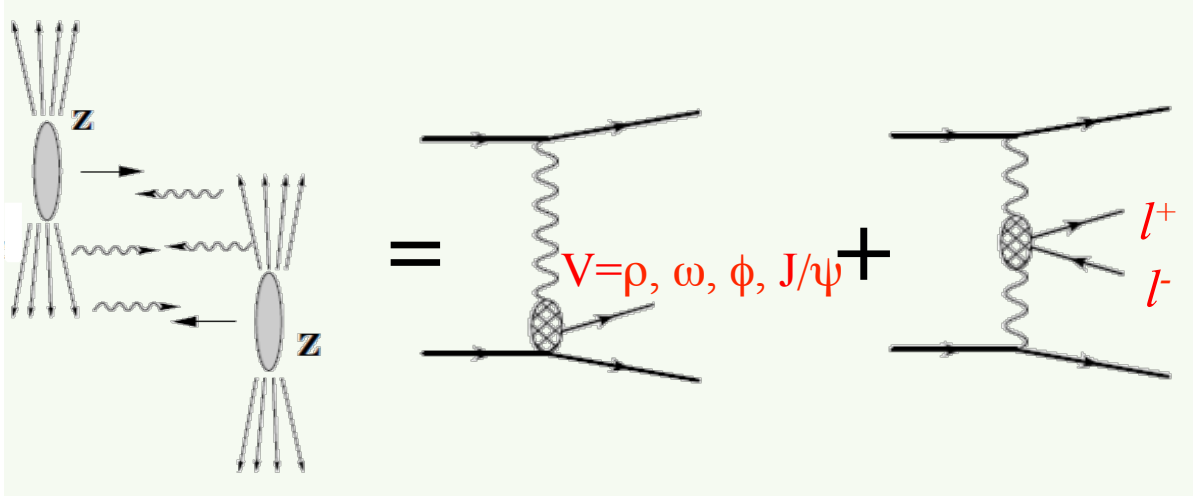
Deflection by magnetic field in QGP?

Coherent Photoproducts in QGP



New probe of QGP:

- EM field
- Deconfinement
- …



EM+QGP:

Chiral Magnetic Effect

Summary

- Significant enhancement of very-low-p_T J/ψ and ee observed in hadronic heavy-ion collisions
- Consistent with expectation of coherent photoproduction
- Broadening of p_T and angular correlation of dilepton
- Provide novel probe of QGP

Outlook:

- ${}_{44}{}^{96}\mathrm{Ru}+{}_{44}{}^{96}\mathrm{Ru}$, ${}_{40}{}^{96}\mathrm{Zr}+{}_{40}{}^{96}\mathrm{Zr}$ vs. ${}_{79}{}^{197}\mathrm{Au}+{}_{79}{}^{197}\mathrm{Au}$
- Beam energy scan program
- …

Thanks!