Vector mesons photoproduction in ultraperipheral ion-ion collisions

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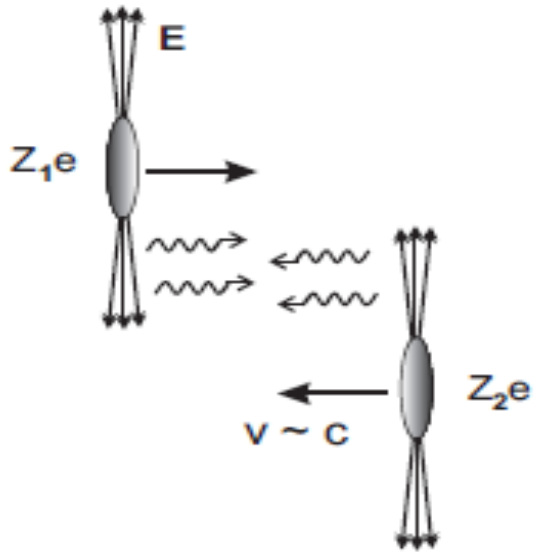
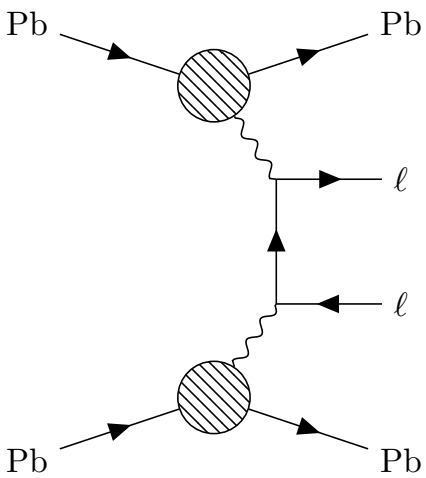
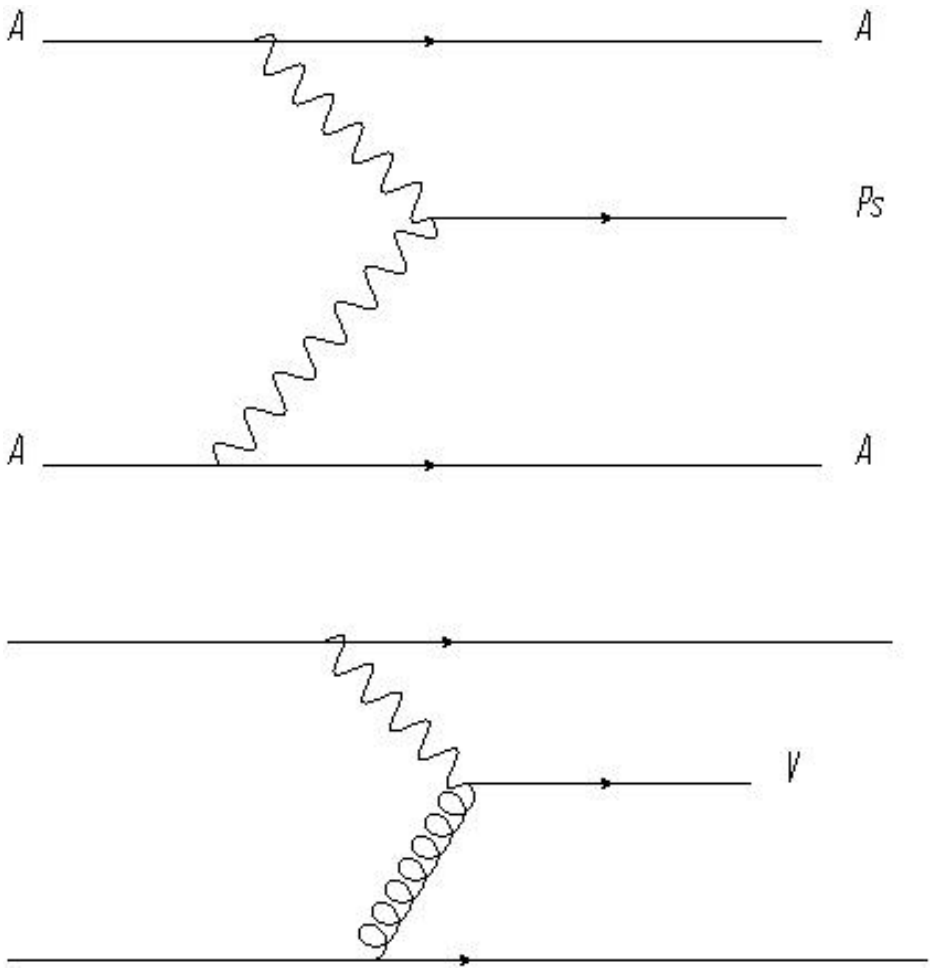
In 1924 Enrico Fermi who was 23 years old proposed that electromagnetic field of moving charge particle is a flux of virtual photons. In ultraperipheral collisions (UPC) of two relativistic ions they interact via cloud of virtual photons. Such processes take plays at large impact parameter $b > R_A + R_B$ and are intensively investigated at STAR $\sqrt{s} = 200 GeV$ and ALICE $\sqrt{s} = 5 TeV$ collaborations.

b>2R Ultraperipheral collisions

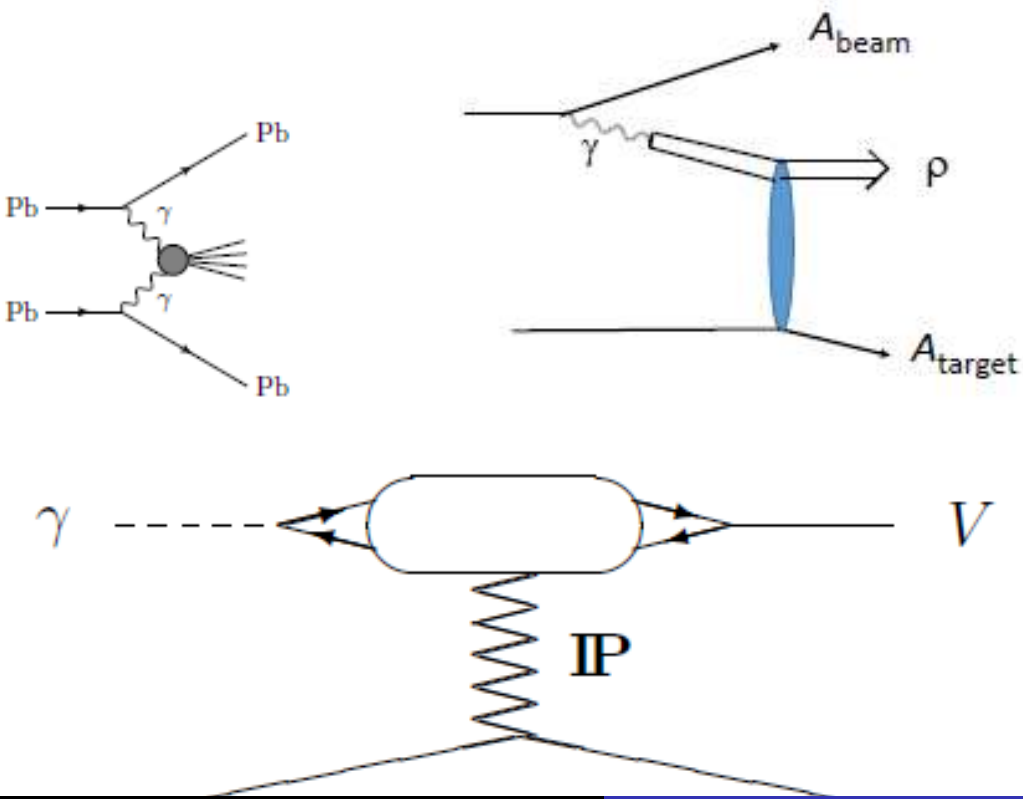


The typical process of such kind is production in UPC lepton pairs $e^+e^-, \mu^+\mu^-, \tau^+\tau^-$ or pseudoscalar and scalar mesons π^0, η, f etc. production in the Coulomb fields of colliding nuclei, which allows one to measure the radiative width of mesons .





The above processes are result of subprcesses $\gamma\gamma \to I^+I^-$ or $\gamma\gamma \to Ps(\pi^0, \eta)...)$. From the other hand there are so call photonuclear processes as for example production in UPC vector mesons $A + B \to A + B + V(\rho, \omega, J/\Psi)$ which is a result of vector meson photoproduction i.e. the subprocess $\gamma + B \to V + B$



$$\frac{d\sigma(AA \to VAA)}{d\omega dp_v^2} = \int \frac{dN}{d\omega dq_\gamma^2}\delta(\vec{p}_v - \vec{q}_\gamma - \vec{q}_A)\frac{d\sigma(\gamma A \to VA)}{dq_A^2}dq_\gamma^2 dq_A^2 \quad (1)$$

The photon flux emitted by ion in momentum space read

$$\frac{dN}{d\omega dq_t^2} = \frac{Z^2\alpha}{\pi\omega}\frac{q_t^2}{(q_t^2 + (\omega/\gamma)^2)^2}F^2(q_t^2) \quad (2)$$

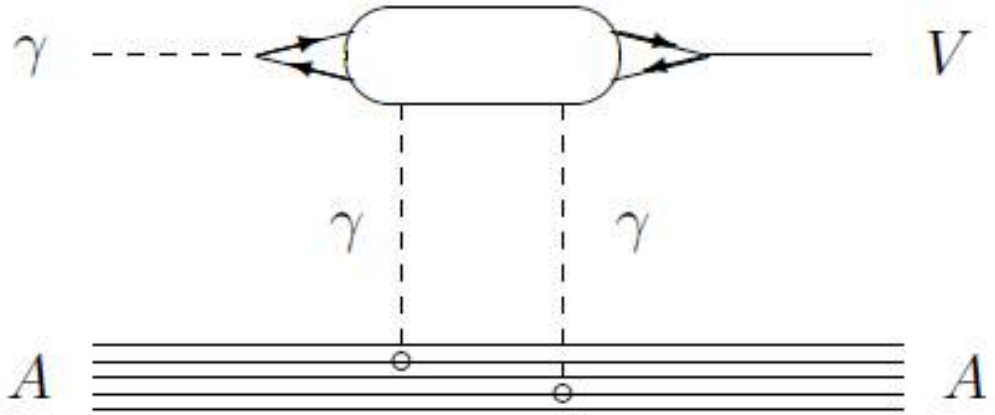
where q_t is the transverse component of radiated photon,ω it energy,$\gamma = \frac{E}{m}$ Lorentz factor and $F(q_t^2)$ nucleus form factor and $y = \log\frac{\omega}{2m_V}$ vector meson rapidity.
The problem now is to obtain correct parameterization for vector meson photoproduction on nuclei.
The simple and wide spread way to calculate the vector mesons photoproduction of heavy nuclei is the Vector Dominance Model where one change the photon interaction with target by interaction of vector meson.

In 2003 we (S.G. ,I.Ivanov, N.Nikolaev hep-ph/0305054) calculated the photoproduction process $\gamma + A \to V(\rho, \omega, \phi) + A$ for any nuclei in the framework of Glauber theory. Despite the pseudoscalar mesons which can be produced in the Coulomb field by one photon exchange the vector meson due to charge conjugation can be photoproduced off Coulomb field by exchange of two photon. We calculated the corresponding diagramm and show that its account leads to strong dependence of photoproduction amplitude slope on photon energy.

$$M_C(\vec{q}) = \frac{\pi e (Z\alpha_{em})^2}{F_V} \langle V|\vec{r}^2|V\rangle \ln \frac{6}{(q^2+\Delta^2)\langle R_A^2\rangle_{ch}} \tag{3}$$

$$= \frac{8\pi e (Z\alpha_{em})^2}{3F_V} \langle \vec{R}_V^2\rangle_{ch} \ln \frac{6}{(q^2+\Delta^2)\langle R_A^2\rangle_{ch}} \tag{4}$$

Full amplitude is a sum of strong amplitude M_S (two gluon exchange) and Coulomb one M_C (two photons exchange)


γ
V
γ
γ
A
A

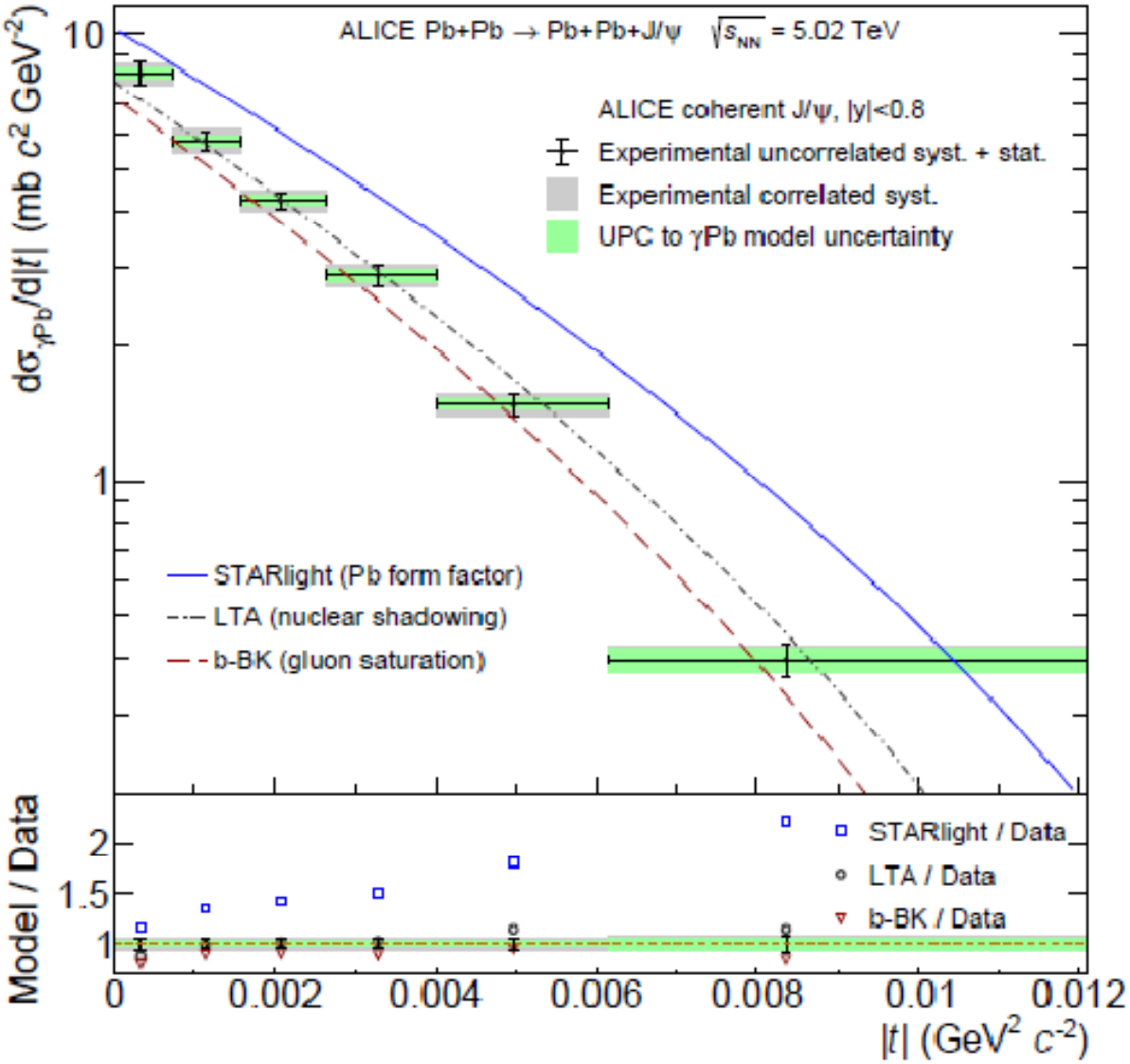
The logarithmic singularity of $M_C(\vec{q})$ makes the Coulomb correction much more noticeable in the diffraction slope

$$B = 2\frac{d\ln M}{d\vec{q}^2} \tag{5}$$

For the slope of the full amplitude

$$B = B_A + \Delta B_C = B_A + \eta_C \frac{1}{\vec{q}^2 + \Delta^2} = B_A + \frac{4\eta_C E_\gamma^2}{m_\rho^4} \cdot \frac{\Delta^2}{\vec{q}^2 + \Delta^2} \tag{6}$$

$\Delta = \frac{m_V^2}{2E}$ longitudinal transfer momenta.
At small transverse momenta the correction from two photon exchange increase which lead to grows of slope which can be checked in ion-ion collisions.


ALICE Pb+Pb → Pb+Pb+J/ψ $\sqrt{s_{NN}}$ = 5.02 TeV
ALICE coherent J/ψ, |y|<0.8
Experimental uncorrelated syst. + stat.
Experimental correlated syst.
UPC to γPb model uncertainty
STARlight (Pb form factor)
LTA (nuclear shadowing)
b-BK (gluon saturation)
$d\sigma_{\gamma Pb}/d|t|$ (mb c^2 GeV^{-2})
10
1
STARlight / Data
LTA / Data
b-BK / Data
Model / Data
2
1.5
1
0
0.002
0.004
0.006
0.008
0.01
0.012
$|t|$ (GeV^2 c^{-2})

Currently we plan to include the considered effect in Monte Carlo generator UPCGEN developed by N.Burmasov and E. Kryshen arxiv/2111.11383 to estimate the impact on vector mesons production in UPC.
As to the possibility of such investigations on NICA it require separate consideration which is under the way. The deal is that photons energy at NICA are less than 2GeV thus vector mesons production demands high luminosity which can be achived by uppgrated nucloton.
In conclusion let us note that besides vector mesons production in UPC at NICA one can extended the measurements of lepton pairs and scalar and pseudoscalar mesons at NICA which as was mentioned above has its additional attractive interest.
Thank you for attention.