Two-photon fusion production of e^+e^- in proton-lead collision

Barbara Linek[1,2]

In collaboration with Marta Łuszczak[2], Wolfgang Schäfer[3] and Antoni Szczurek[2,3]

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[1]Doctoral School of the University of Rzeszow, Poland [2]Institute of Physics, University of Rzeszow, Poland

[2]The Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences

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Introduction

- γ-γ processes in nucleus-nucleus collisions are separated into real-hadron collisions ($b < R_1 + R_2$) and ultraperipheral collisions ($b > R_1 + R_2$);

- Two-photon processes survive also in semi-central collisions in which dominate at very small transverse momenta of the dilepton;

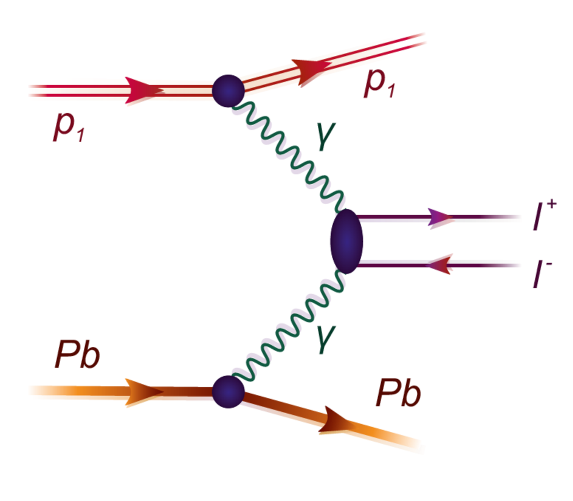
- There are not careful analyses of gamma-gamma processes in proton-nucleus collisions;

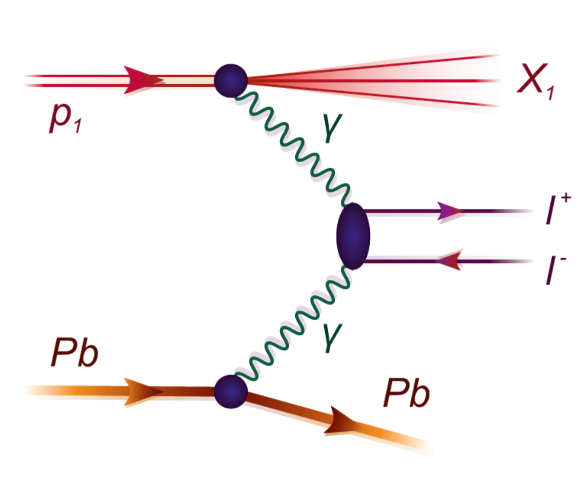
- The last year's ALICE experimental analysis allows to thoroughly investigate the contribution of photon-initiated production of e^+e^- in proton-nucleus collisions and compare the results to experimental data;

Introduction

- There are analysed only two types of processes: double-elastic and single dissociation because of being a source of „elastic" photons through the nucleus;
- The used formalism is the k_T - factorization approach;
- This analysis covers four approaches to structure functions;
- Dilepton production with rapidity gap between the nucleus and high-p_T leptons is suggested to be a probe of the photon partonic content of the proton.

Classes of $\gamma\gamma \to l^+l^-$ mechanism and k_T – factorization approach





The cross section for production of l^+l^- in proton-lead collisions in the k_T – factorization approach can be written as:

$$\sigma = S^2 \int dx_p dx_{Pb} \frac{d^2\overrightarrow{q_T}}{\pi} \left[\frac{d\gamma_{el}^{p}(x_p, Q^2)}{dQ^2} + \frac{d\gamma_{inel}^{p}(x_p, Q^2)}{dQ^2} \right] \times \gamma_{el}^{Pb}(x_{Pb}, Q^2)\, \sigma_{\gamma^*\gamma \to l^+l^-}(x_p, x_{Pb}, \overrightarrow{q_T})$$

Fluxes of elastic photons

The proton elastic flux is expressed by the proton electromagnetic form factor:

$$\frac{d\gamma_{el}^{p}(x_p, Q^2)}{dQ^2} = \frac{\alpha_{em}}{\pi}\left\{\left(1-\frac{x}{2}\right)^2 \frac{4m_p^2 G_E^2(Q^2) + Q^2 G_M^2(Q^2)}{4m_p^2 + Q^2} + \frac{x^2}{4} G_M^2(Q^2)\right\}$$

For the nucleus elastic flux the following is replaced:

$$\frac{4m_p^2 G_E^2(Q^2) + Q^2 G_M^2(Q^2)}{4m_p^2 + Q^2} \to Z^2 F_{em}^2(Q^2), \qquad F_{em}(Q^2) = \frac{3}{(QR_A)^3}\left[\sin(QR_A) - QR_A\cos(QR_A)\right]\frac{1}{1+a^2Q^2}$$

The high-energy factorization

The inelastic flux is expressed by the proton structure functions $F_1(x_{Bj},Q^2)$ and $F_2(x_{Bj},Q^2)$:

$$\frac{d\gamma^{p}_{inel}(x_p,Q^2)}{dQ^2} = \frac{1}{x}\int_{M^2_{thr}} dM_X^2\, \mathcal{F}^{in}_{\gamma^*\leftarrow p}(x,\vec{q}_T^{\,2},M_X^2)$$

where:

$$\mathcal{F}^{in}_{\gamma^*\leftarrow p}(x,\vec{q}_T^{\,2},M_X^2) = \frac{\alpha_{em}}{\pi}\left\{(1-x)\left(\frac{\vec{q}_T^{\,2}}{\vec{q}_T^{\,2}+x(M_x^2-m_p^2)+x^2m_p^2}\right)^2\frac{F_2(x_{Bj},Q^2)}{Q^2+M_X^2-m_p^2}+\frac{x^2}{4x_{Bj}^2}\frac{\vec{q}_T^{\,2}}{\vec{q}_T^{\,2}+x(M_X^2-m_p^2)+x^2m_p^2}\frac{2x_{Bj}F_1(x_{Bj},Q^2)}{Q^2+M_X^2-m_p^2}\right\}$$

In practice we use function $F_L(x_{Bj},Q^2)$ instead of $F_1(x_{Bj},Q^2)$:

$$F_L(x_{Bj},Q^2) = \left(1+\frac{4x_{Bj}^2m_p^2}{Q^2}\right)F_2(x_{Bj},Q^2) - 2x_{Bj}F_1(x_{Bj},Q^2)$$

Structure functions arguments

- Photon virtuality:

$$Q^2 = \frac{\vec{q}_T^{\,2} + x\left(M_X^2 - m_p^2\right) + x^2 m_p^2}{1-x};$$

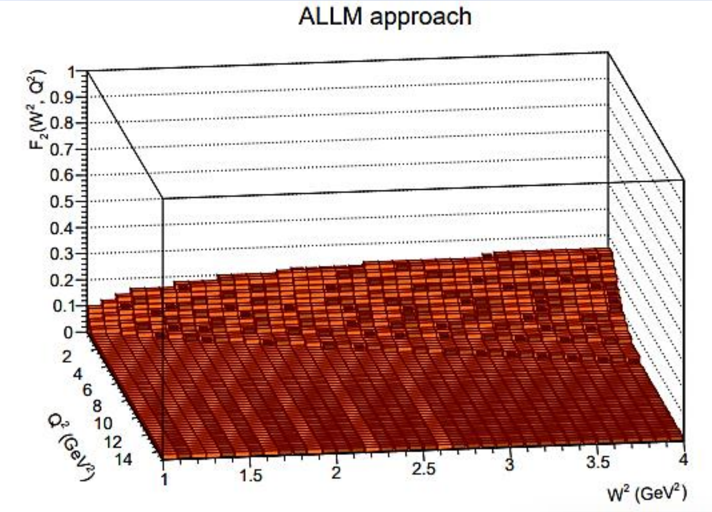
- Bjorken-x:

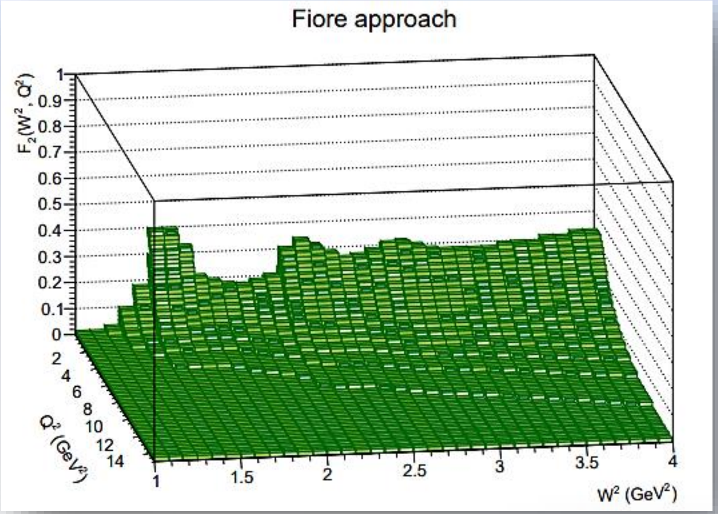
$$x_{Bj} = \frac{Q^2}{\left(Q^2 + M_X^2 - m_p^2\right)};$$

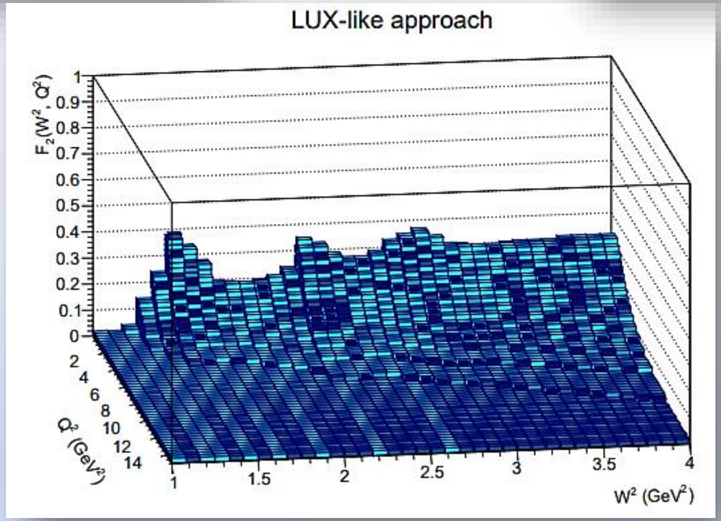
- Invariant mass of the hadronic final state:

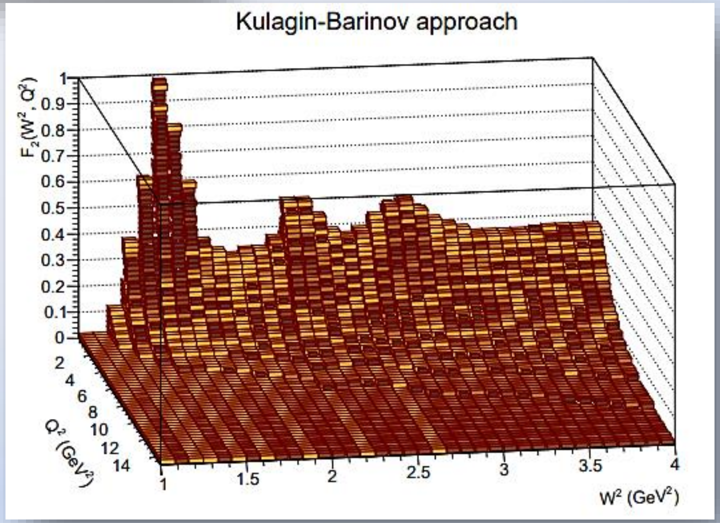
$$W^2 = \frac{1 - x_{Bj}}{x_{Bj}} Q^2 + m_p^2;$$

Different parametrizations of structure functions depending on W^2 and Q^2

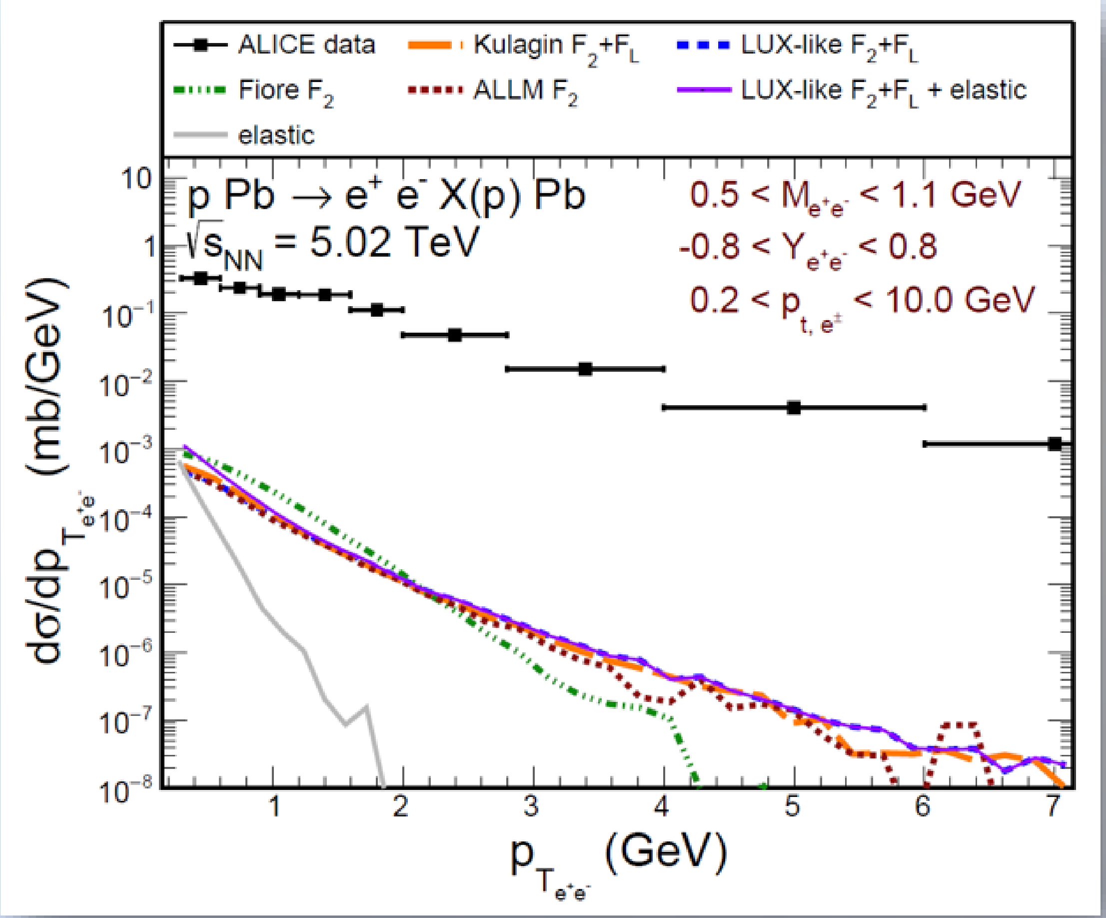


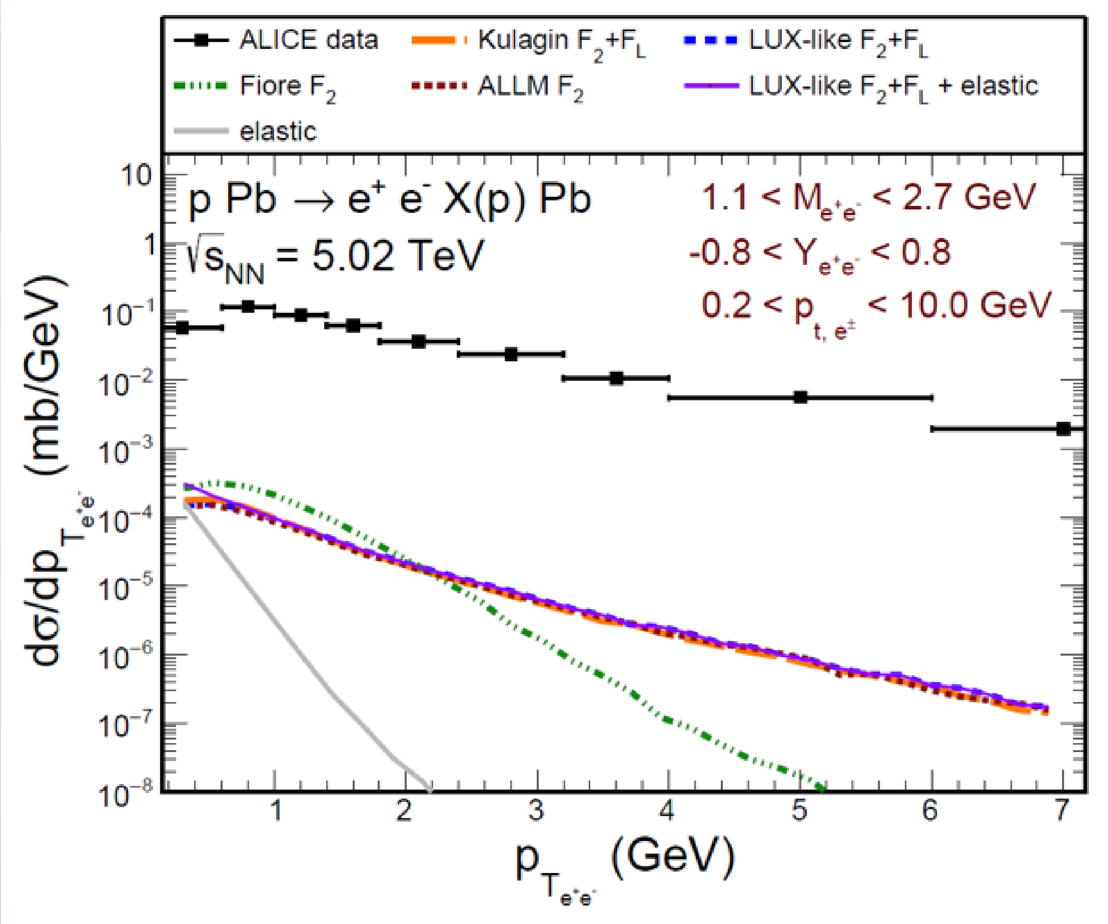






Distributions in $p_{T_{e^+e^-}}$





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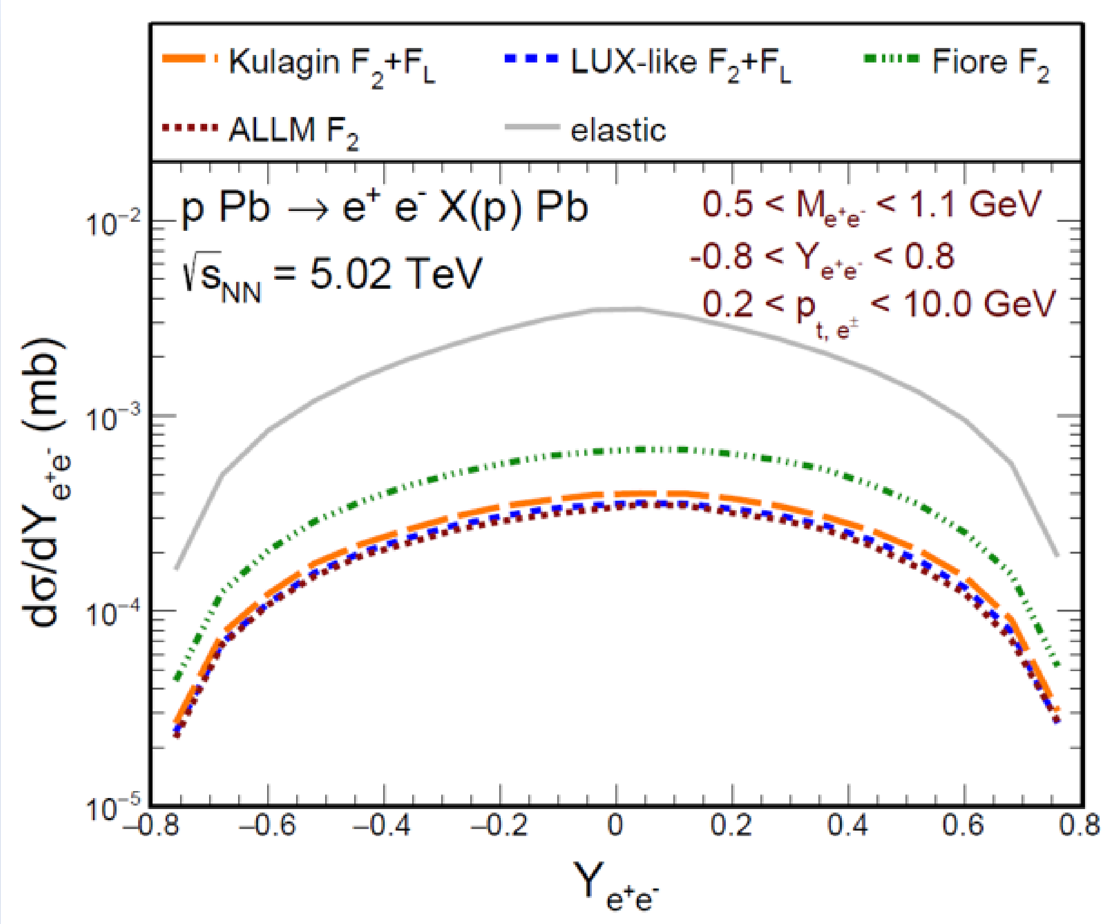
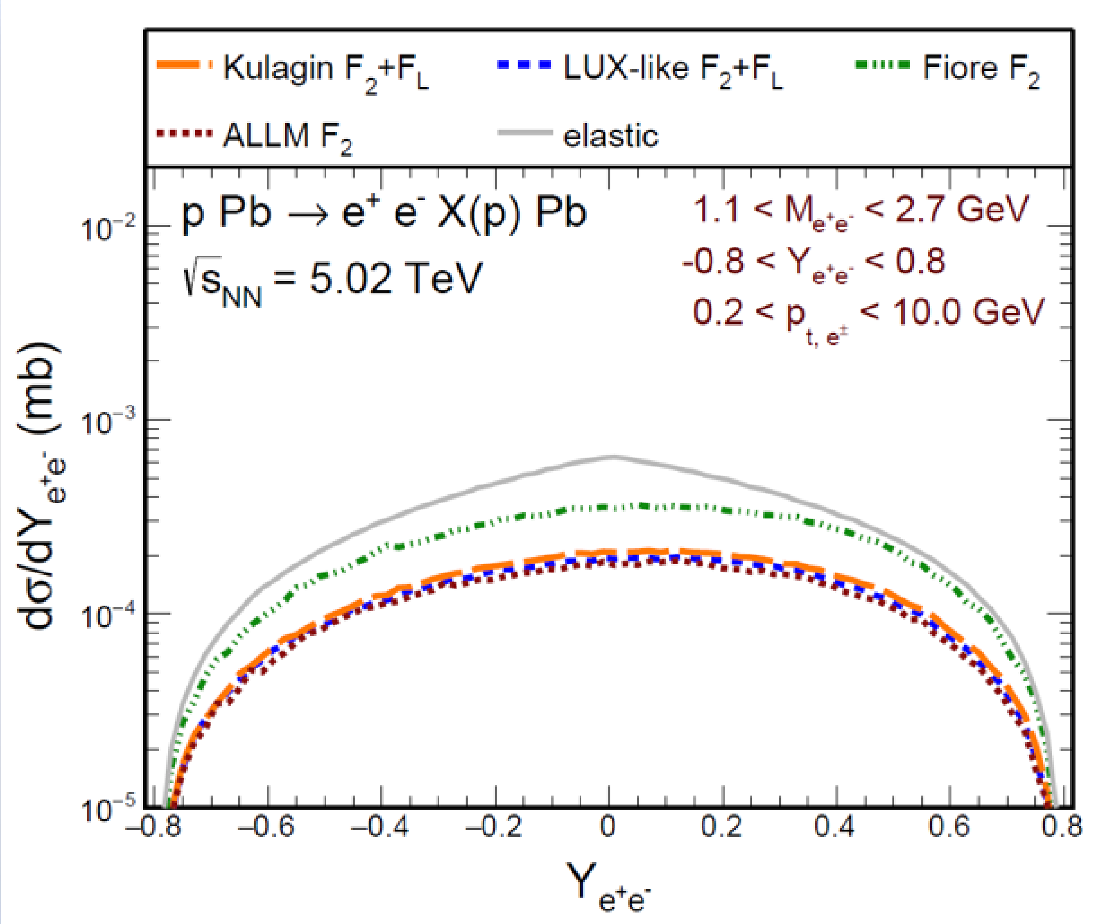
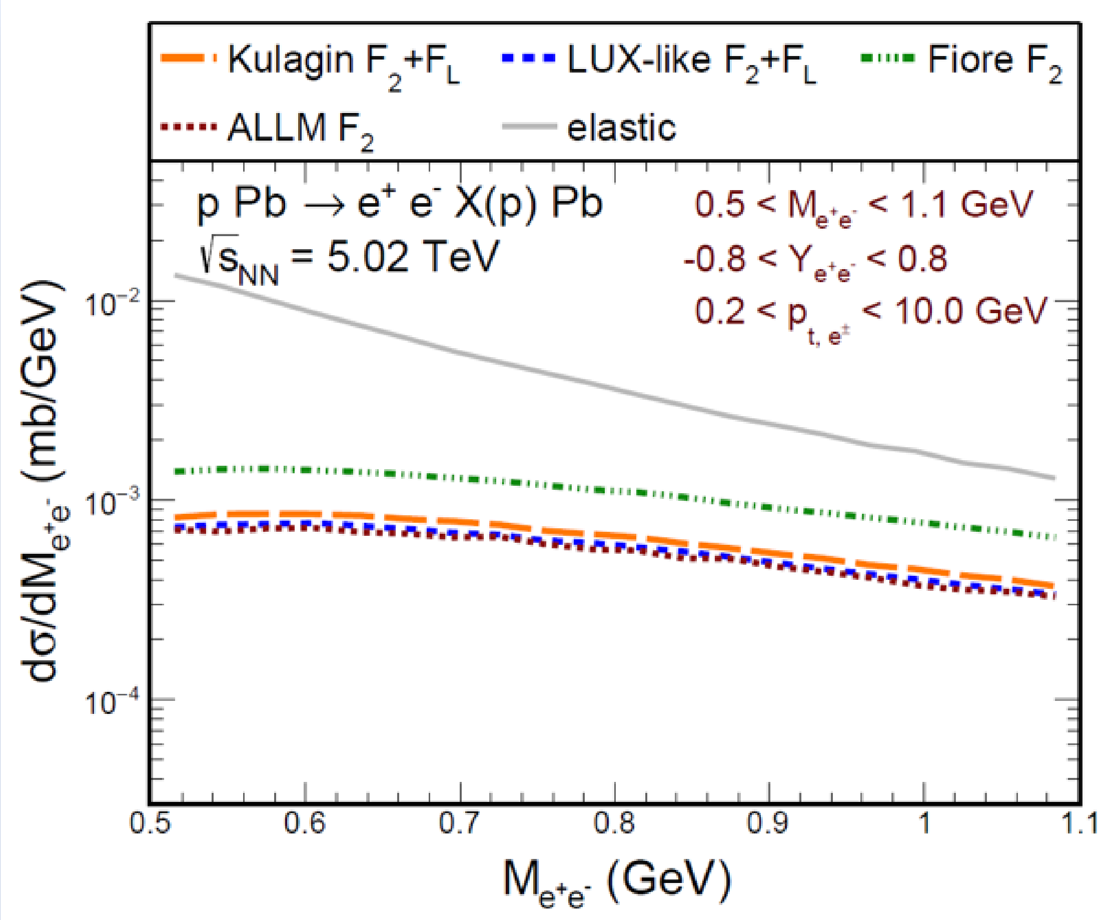
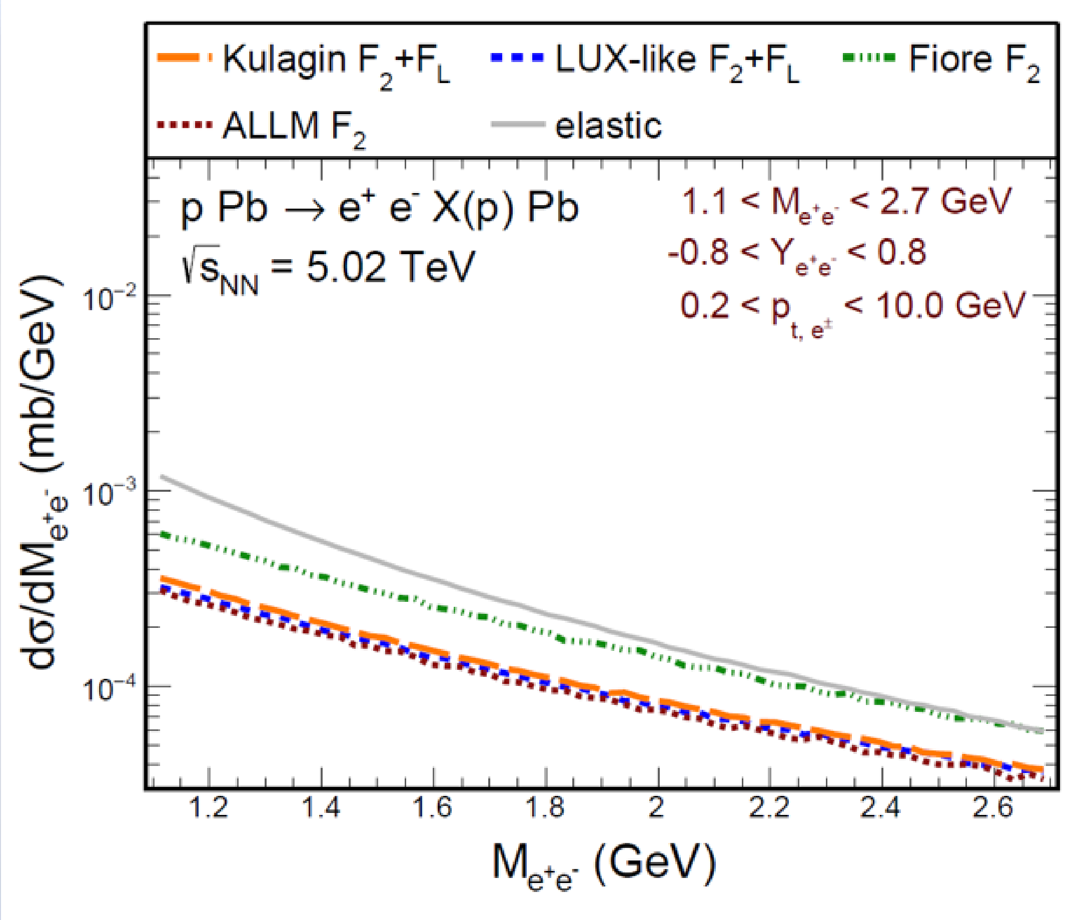
Distributions in $Y_{e^+e^-}$



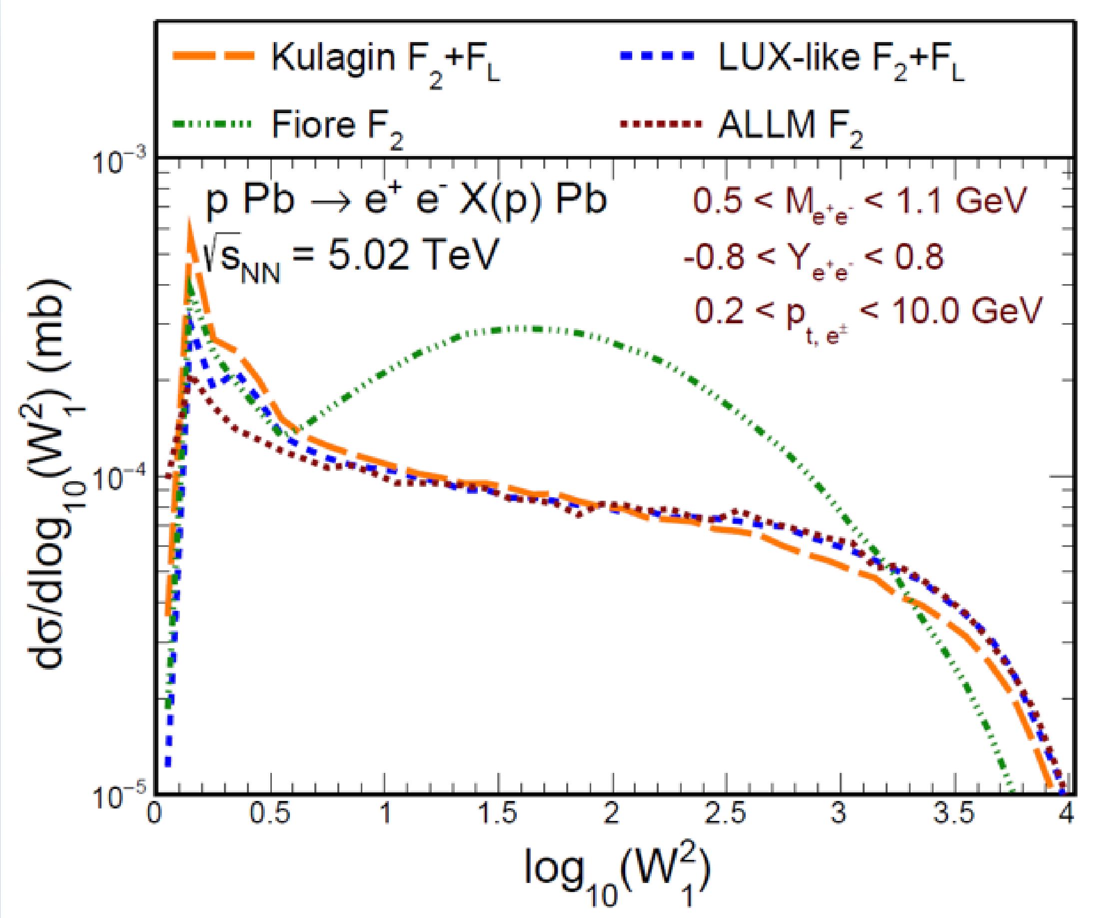


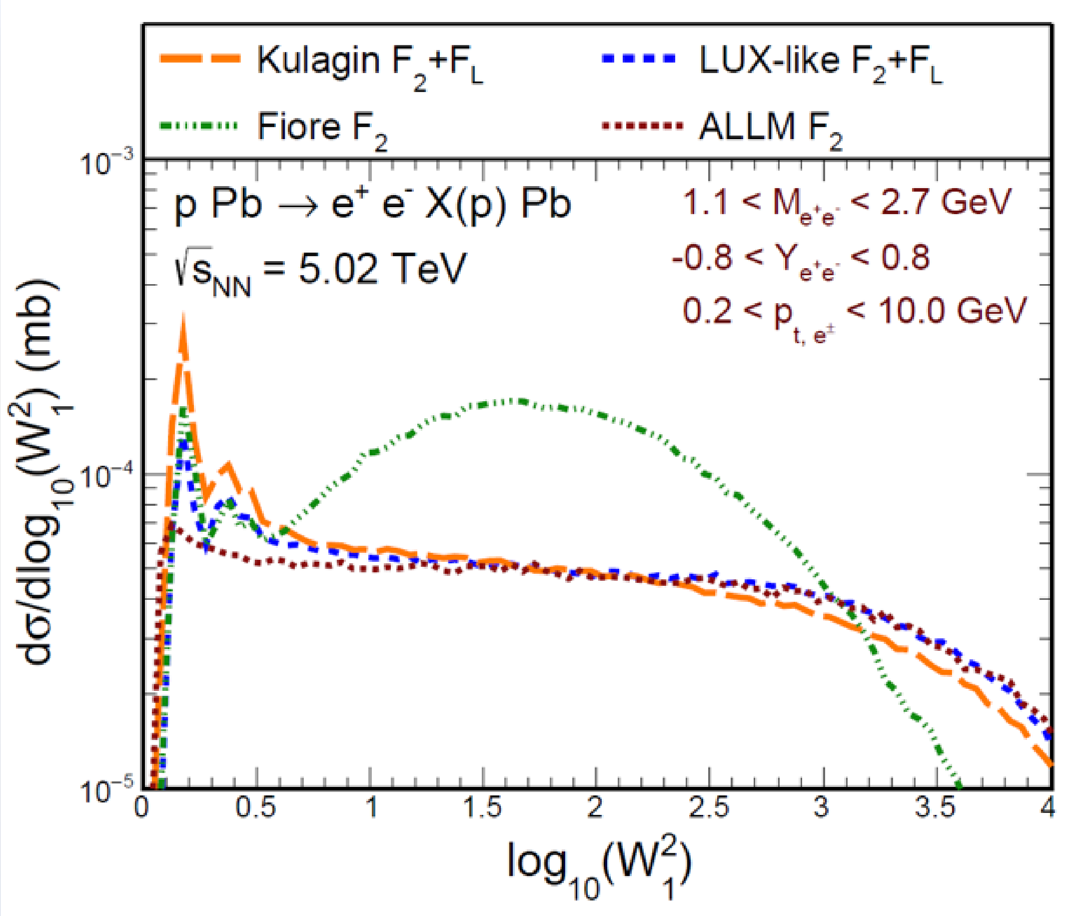
Distributions in $M_{e^+e^-}$



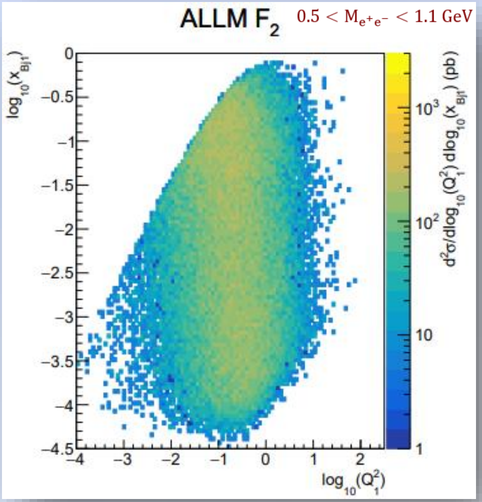


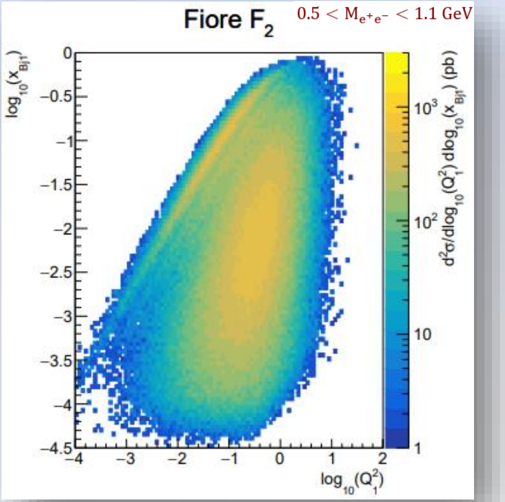
Distributions in $\log_{10}(W_1^2)$

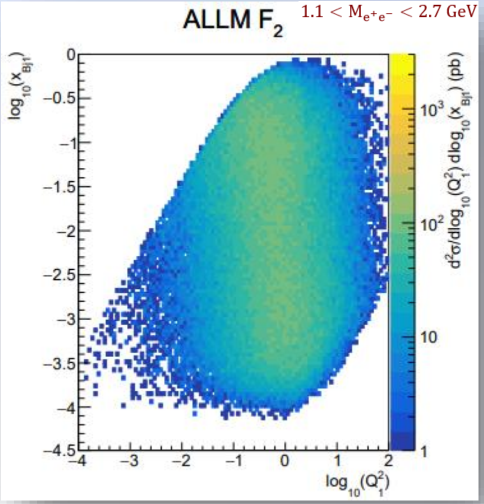


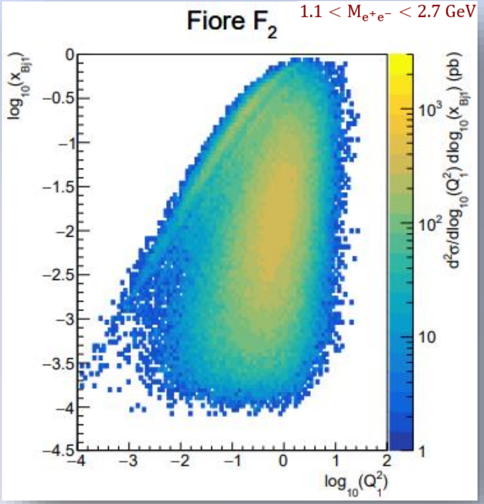


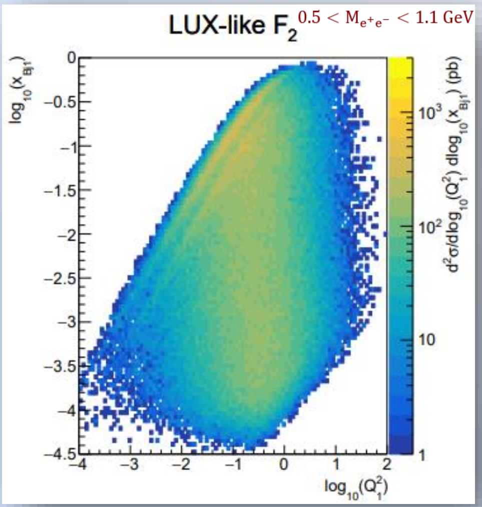
Distributions in $\log_{10} x_{Bj}$ and $\log_{10} Q^2$

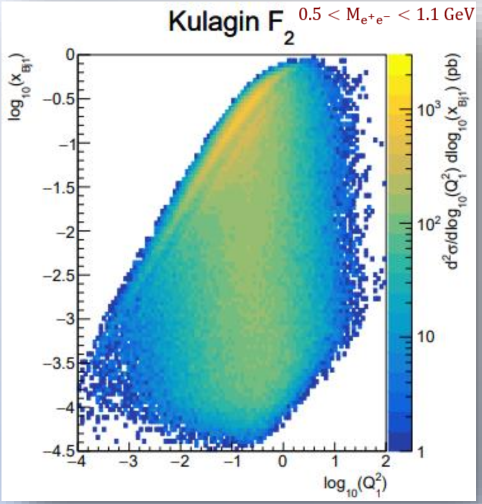


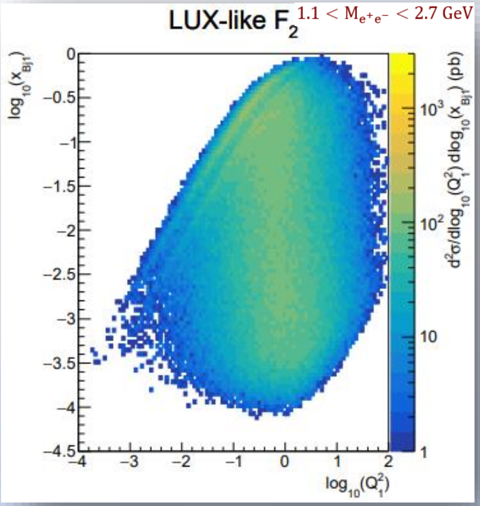


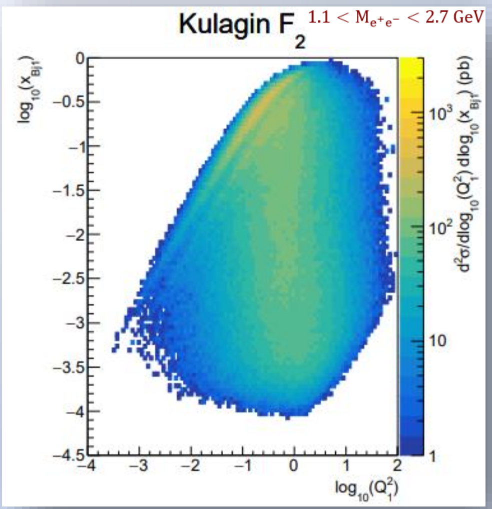




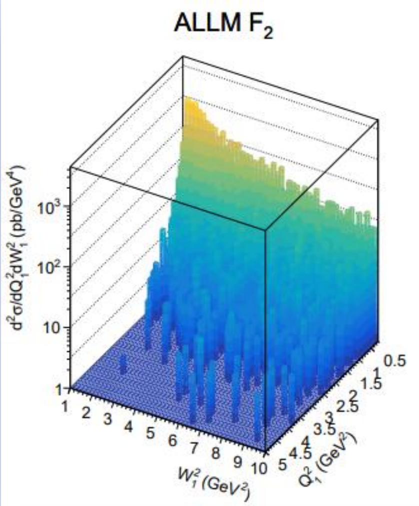


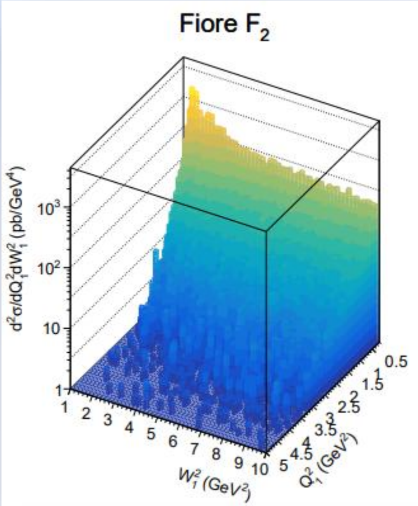


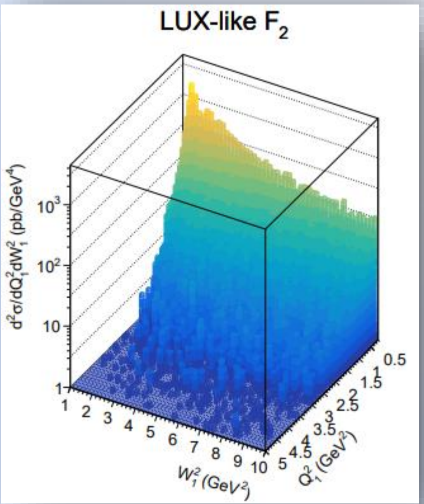


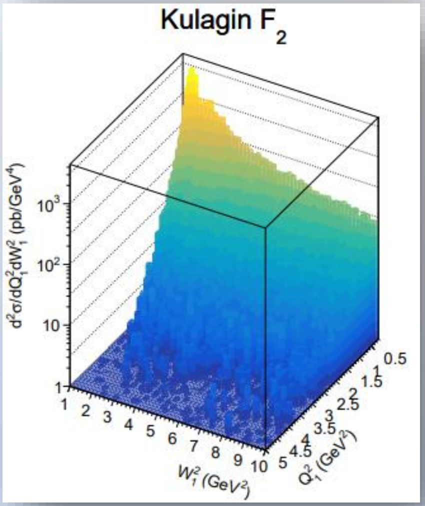


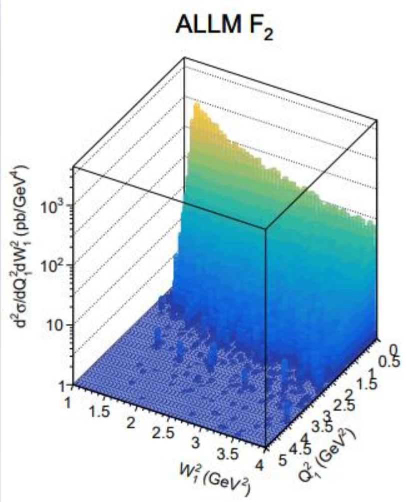
Distributions in W^2 and Q^2

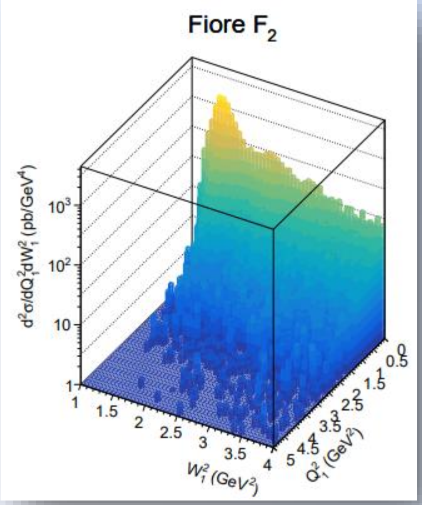


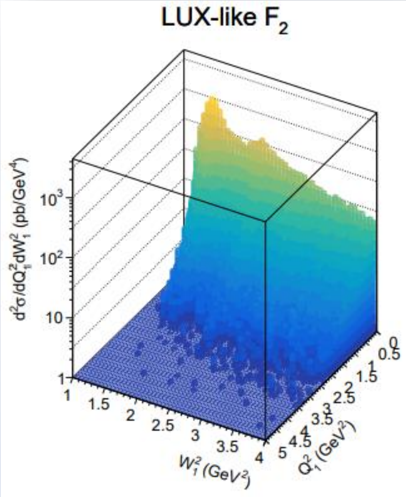


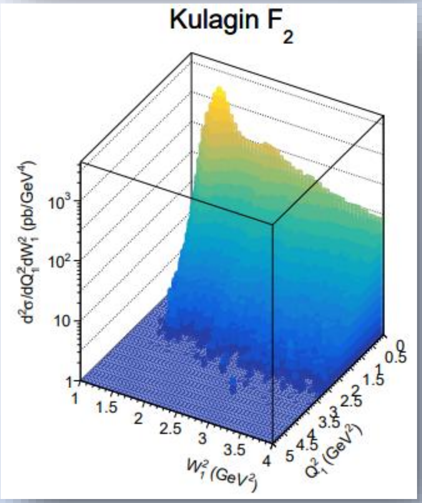












Total cross section for different approaches

Structure function approaches	σ_{LMR} (nb)	σ_{IMR} (nb)
elastic	2938.72	507.04
LUX-like	346.53	191.40
Kulagin-Barinov	387.93	205.27
Fiore et al.	653.07	347.08
ALLM	329.72	179.07

Total cross section from SuperChic generator including gap survival factor

Mass region	*Without soft S_G (nb)*	*With soft S_G (nb)*	$\langle S_G \rangle$
$0.5 - 5\ (GeV)$	755.91	718.84	0.95
$5 - 10\ (GeV)$	687.74	623.27	0.91
$10 - 15\ (GeV)$	98.68	87.01	0.88
$15 - 20\ (GeV)$	28.23	24.33	0.86

Conclusions

- We have calculated the photon-photon contribution to the inclusive production of e^+e^- pair in proton-lead collisions;
- Our results are compared to the existing data measured by ALICE collaboration;
- Although the contribution of two-photon processes is negligible, however it is interesting and could be experimentally tested in the future;
- It was shown the sensitiveness to the nonperturbative regions and broad range of Bjorken-x;
- Various parametrizations used treat this area of structure functions slightly differently and Fiore et al. parametrization is the most different from the others;
- The gap survival factor depends on the dielectron invariant mass decreasing the cross section by $5\% - 15\%$.

Thank you for your attention