Production and two-photon decay of η_c at energy of SPD NICA

A. Anufriev[1], V. Saleev[1,2]

[1] Samara National Research University, [2] Joint Institute for Nuclear Research

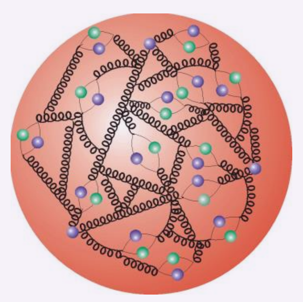
Relevance

- The planned study by the SPD NICA collaboration of the processes of the birth of η_c mesons in proton-proton interactions requires a preliminary calculation of the signal-background ratio to assess the possibility of measuring the cross-section of the birth of η_c mesons
- The verification of various models of the hadronization of a pair of charmed quarks and antiquarks into a charmonium is essential for testing the factorization hypothesis.

Collinear Parton Model

$$q^\mu = xP^\mu, \text{ where } P^\mu = \frac{\sqrt{S}}{2}(1,0,0,\pm1)$$

$$d\sigma = \sum_{i,j,l=q,\bar{q},g} \int_0^1 dx_1 \int_0^1 dx_2\, f_i(x_1,\mu) f_j(x_2,\mu)\, d\hat{\sigma}(ij \to kl)$$



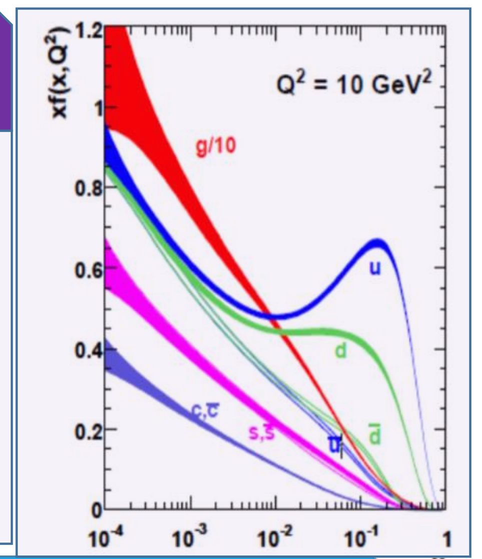
Generalized Parton Model

$$d\sigma = \sum_{i,j,l=q,\bar{q},g} \int_0^\infty dq_{1t}^2 \int_0^\infty dq_{2t}^2 \int_0^1 dx_1 \int_0^1 dx_2\, F_i(x_1,q_t,\mu) F_j(x_2,q_t,\mu)\, d\hat{\sigma}(ij \to kl)$$

$$F_i(x,q_t,\mu) = f_i(x_1,\mu) G(q_t),\quad G(q_t) = \frac{e^{-q_t^2/<q_t^2>}}{\pi < q_t^2 >}$$

Hadronisation mechanism

- Color Singlet Model (CSM): only $c\bar{c}$–pairs with matched quantum number of the charmonium, 1^1S_0 for η_c–meson.
- Non-relativistic QCD (NRQCD): all $c\bar{c}$–pairs of different color and spin sates fragmenting with different probabilities long distance matrix elements (LDME)
- Color Evaporation Model (CEM): all $c\bar{c}$–pairs with mass less than $D\bar{D}$ threshold. One hadronization parameter for each charmonium



η_c production

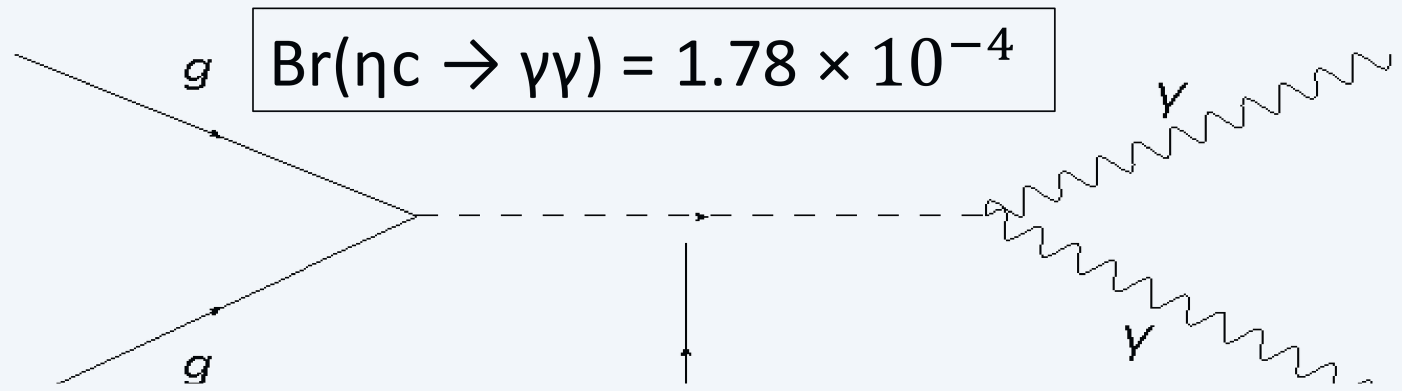
$$\eta_c = c\bar{c}[1^1S_0],\ M(\eta_c) = 2.981 \text{ GeV},\ \Gamma = 29.7 \text{ MeV}$$

$Br(\eta_c \to p\bar{p}) = 1.4 \times 10^{-3}$

$Br(\eta_c \to \Lambda\bar{\Lambda}) = 9.4 \times 10^{-4}$

$Br(\eta_c \to K\bar{K}\pi) = 7.2 \times 10^{-2}$

$Br(\eta_c \to \gamma\gamma) = 1.78 \times 10^{-4}$



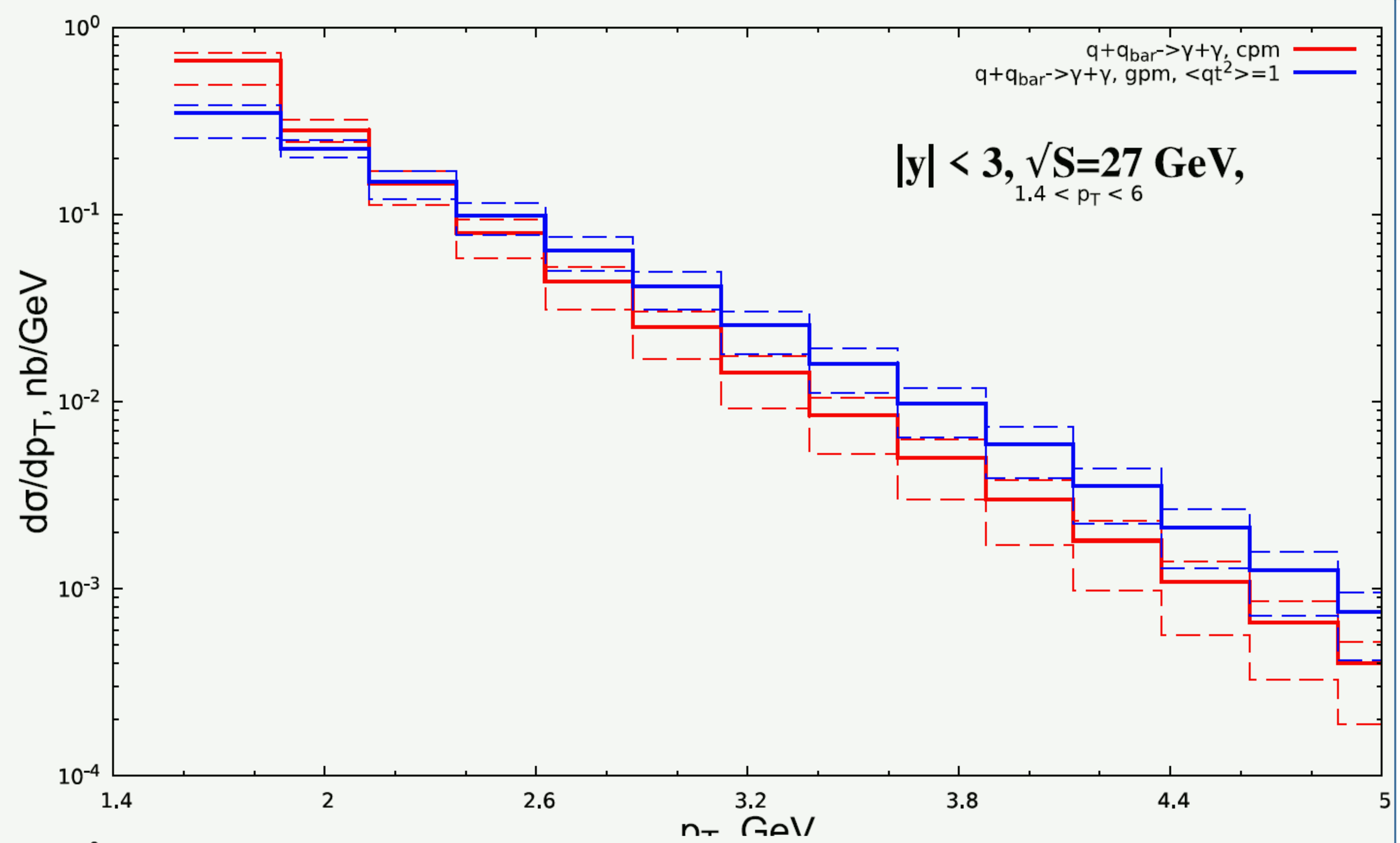
$$A^{\alpha\beta\mu\nu} = f_{gg} f_{\gamma\gamma} \varepsilon^{\alpha\beta\alpha'\beta'} q_1^{\alpha'} q_2^{\beta'} \frac{i}{p^2 - M^2 + iM\Gamma} \varepsilon^{\mu\nu\mu'\nu'} k_1^{\mu'} k_2^{\nu'}$$

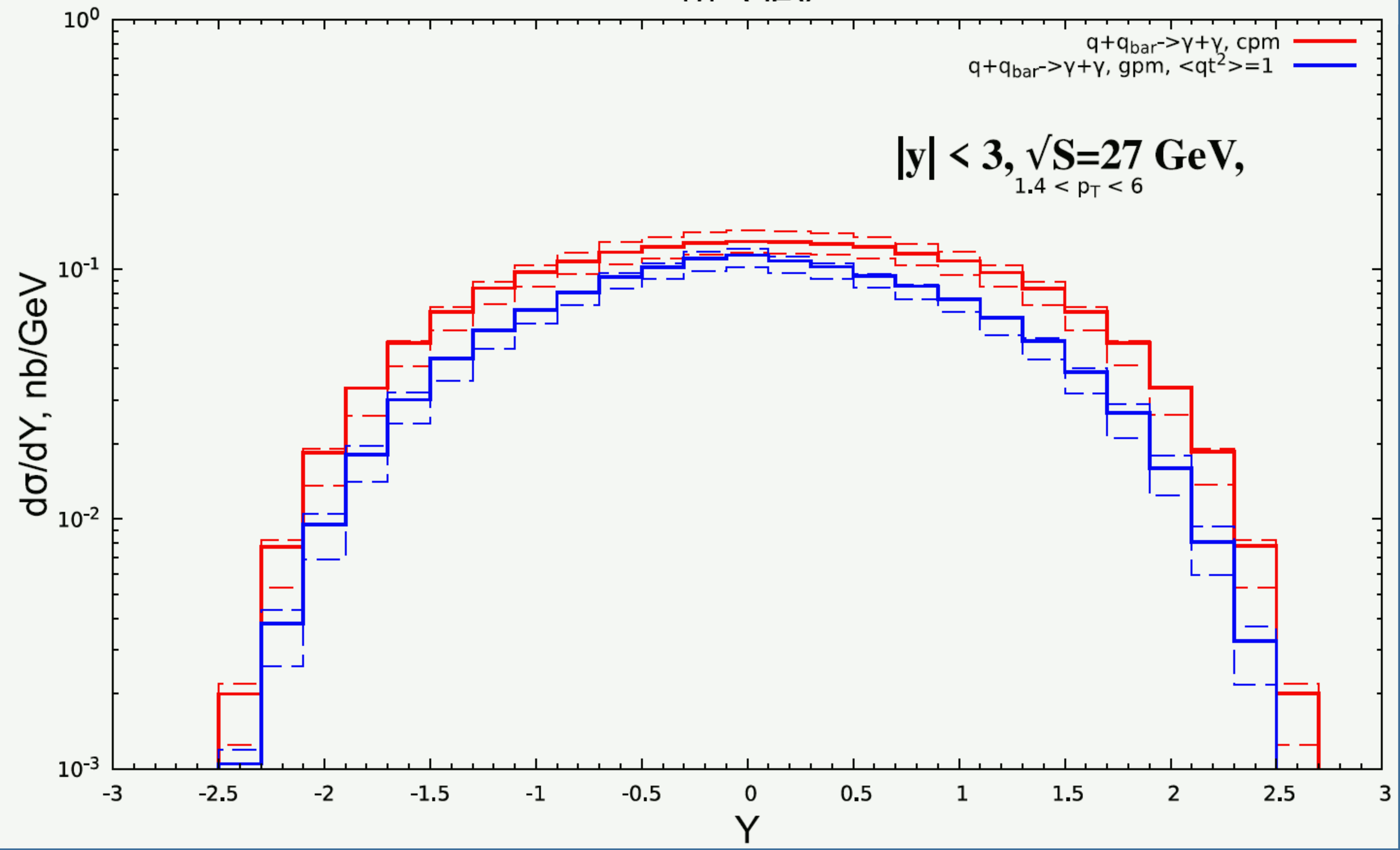
$$|\bar{M}|^2 = \frac{1}{256} \frac{M_0^8 f_{\gamma\gamma}^2 f_{gg}^2}{4(M^2 - M_0^2)^2 + M_0^2\Gamma^2}$$

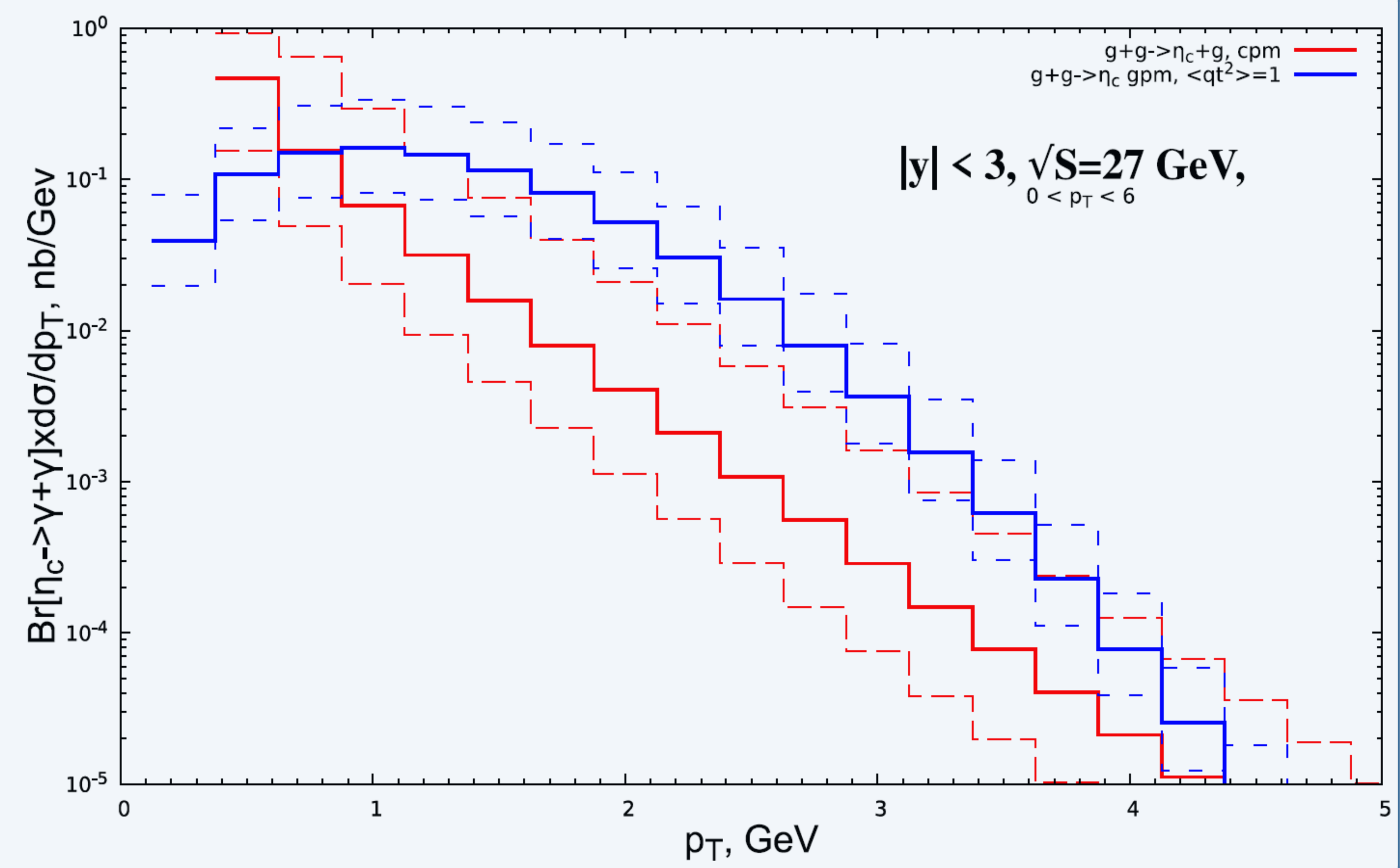
Two-photon production

Direct $q + \bar{q} \to \gamma + \gamma$

Fragmentation
$q + q \to q(\to \gamma) + q(\to \gamma)$
$g + g \to q(\to \gamma) + \bar{q}(\to \gamma)$
$q + g \to q(\to \gamma) + g(\to \gamma)$







Fragmentation

$$d\sigma(pp \to mn) = \sum_{i,j,l,k=q,\bar{q},g} \int_0^1 dx_1 dx_2\, f_i(x_1,\mu) f_j(x_2,\mu) \int_0^1 dz_3 D_{l\to m}(z_3) \int_0^1 dz_4 D_{l\to n}(z_4)\, d\hat{\sigma}(ij \to kl)$$

pp → π_0 (→ γγ) + π_0 (→ γγ)X at the SPD NICA

$q + q \to q(\to \pi_0) + q(\to \pi_0)$

$g + g \to q(\to \pi_0) + \bar{q}(\to \pi_0)$

$q + g \to q(\to \pi_0) + g(\to \pi_0)$

Freagmentation Functions

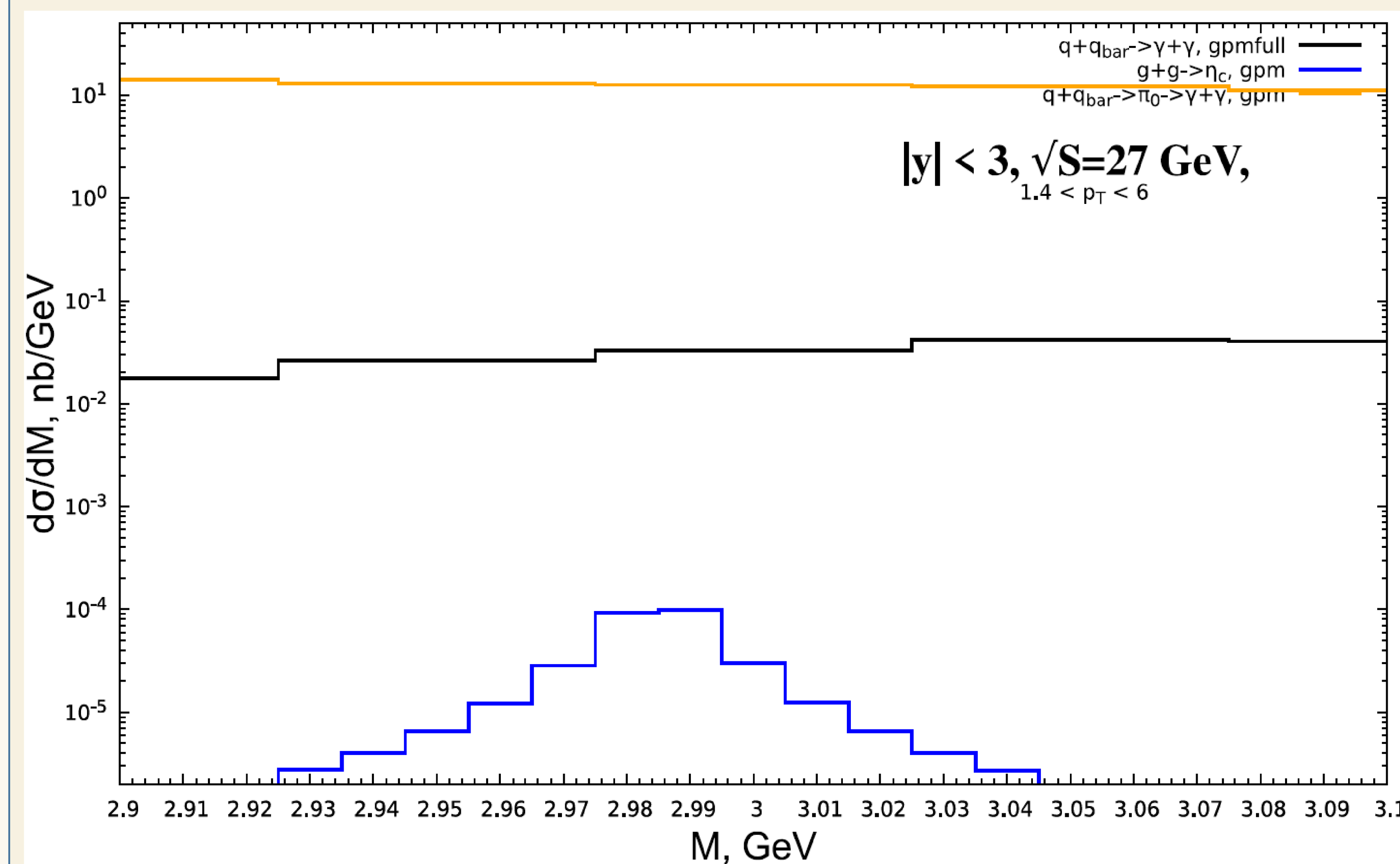
$$D_u^{\pi^0}(z) = \frac{1}{2}\left(D_u^{\pi^+}(z) + D_u^{\pi^-}(z)\right)$$

$$zD_u^{\pi^+}(z) = a\sqrt{z}(c - z) + \xi_\pi(1-z)^2$$

$$zD_u^{\pi^-}(z) = \xi_\pi(1-z)^2$$

$$zD_g^{\pi^0}(z) = C_\pi(1-z)^{1.5}$$

η_c production signal with direct photons and from π_0 production as background



Conclusions

- pp → $\pi_0\pi_0 X$ with π_0 → γγ is main source of photon pairs with invariant mass in the range of M ~ 3 GeV.
- The S/B ratio for pp → η_cX → γγ to processes of prompt photon pair production pp → γγ estimates as ~ 10^{-3}.
- There is dependence on photon transverse momenta ($p_{T_{\gamma min}}$) for S/B ratio.
- However, it should be noted that if the value limiting the contribution of soft photons is not the transverse momentum of photons, but their energy, then S/B ratio may increase. Such an analysis is also planned to be carried out.