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Study of signal and background events in J/ψ +γ production at SPD NICA.

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We study the possibility to measure associated J/psi + y production at NICA energies because this process was proposed as a pure channel for studying the gluon distribution function of a proton

J/ψ decay:

$J/\psi(3S_1^{(1)}) \rightarrow \mu^+ + \mu^-$

A registered pair $\mu^+ \mu^-$ is a candidate for a J/ψ.

Invariant mass of a muon pair:

$$m_{inv} = \sqrt{2\left(m_\mu^2 - (\vec{p}_1 \vec{p}_2)\right) + \sqrt{m_\mu^2 + \vec{p}_1^{\,2}}\sqrt{m_\mu^2 + \vec{p}_2^{\,2}}} \quad (1)$$

m_μ — muon mass, $\vec{p}_i$ — the momentum vector of the i-th particle in a pair.

Probabilities:
– Register muon: 80%
– Misidentify a pion as a muon: 1%

$$W(p, p_{true}) = \frac{e^{-\left(\frac{p - p_{true}}{\sqrt{2}\cdot 0.015\, p_{true}}\right)^2}}{\sqrt{2\pi}\cdot 0.015\, p_{true}} \quad (2)$$

$W(p, p_{true})$ — the probability density to obtain the experimental value of the muon momentum p while the exact value of the muon momentum is p_{true} .

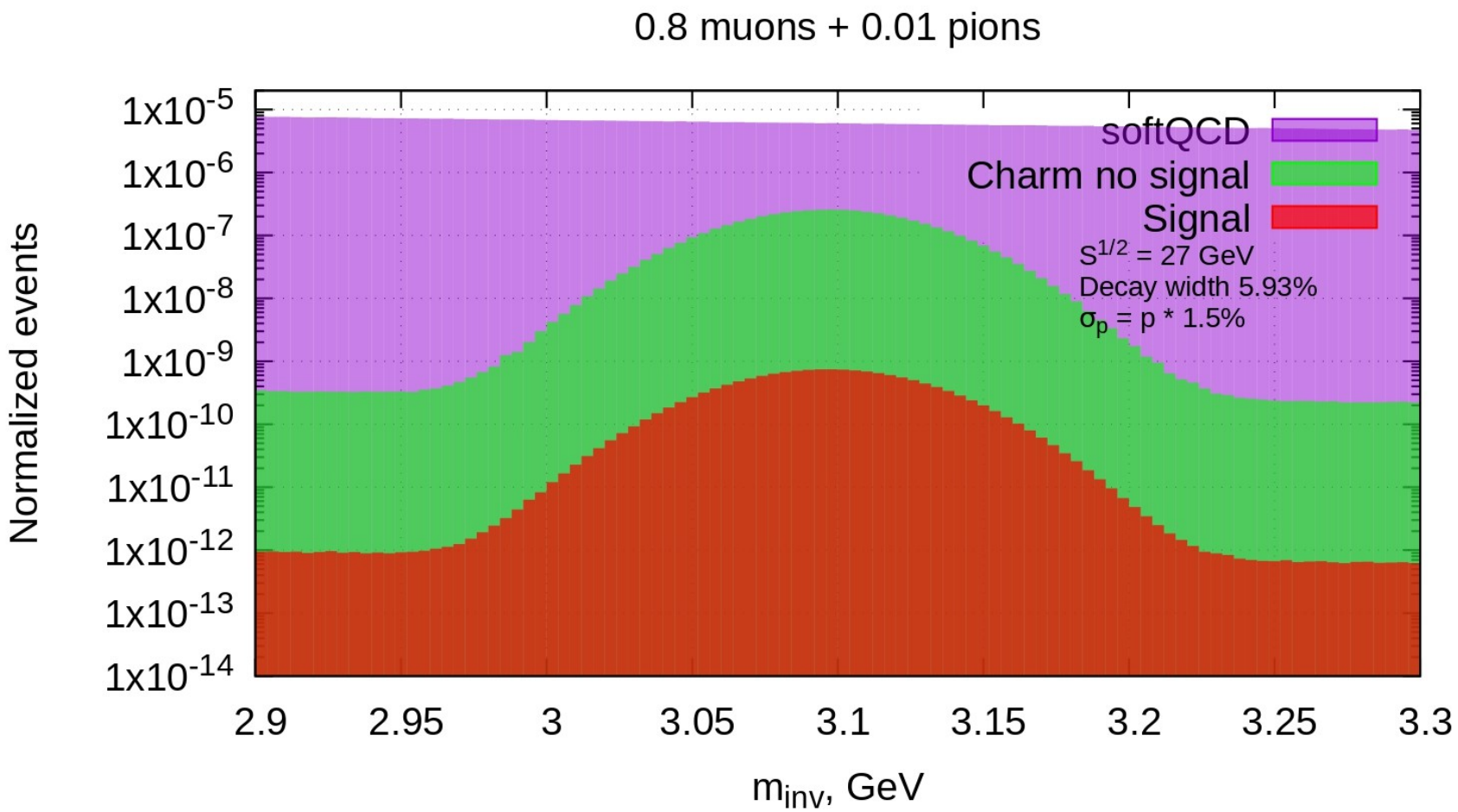


Fig. 1: invariant mass distributions at an energy of $S^{1/2}$=27 GeV

Signal process:

$$g+g \to J/\psi\left(3S_1^{(1)}\right)+\gamma$$

Charmonium from background processes:

$$g+g \to c\bar{c}\left(3S_1^{(1)}\right)+g,$$

$$q+g \to c\bar{c}\left(3S_1^{(8)}\right)+q,$$

$$q+\bar{q} \to c\bar{c}\left(3S_1^{(8)}\right)+g, \text{ etc}$$

SoftQCD:
all soft processes included in the pythia

Distribution of μ+ and μ- by transverse momentum

Chosen cut: $pT_+ + pT_- > 1.25\,\mathrm{GeV}$

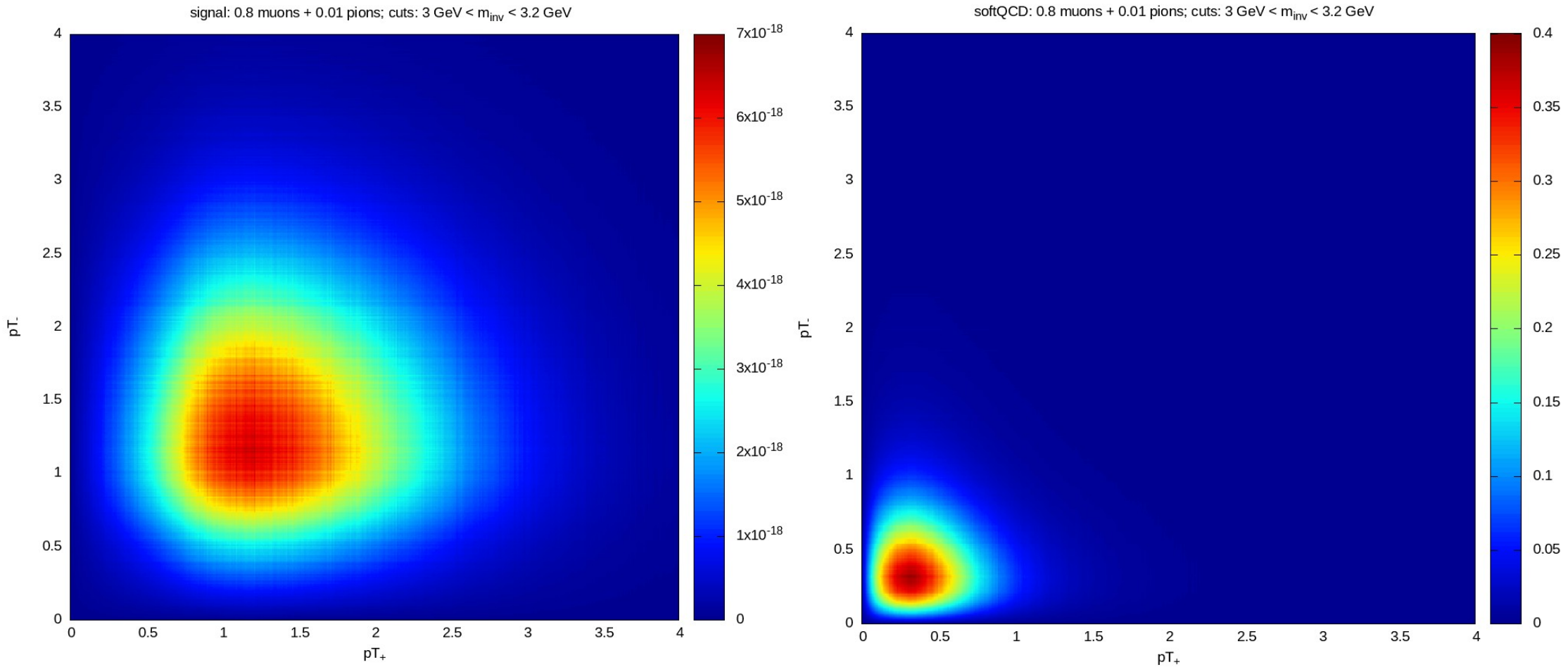


Fig. 2: J/ψ candidates distribution by (pT) of their forming (μ^+, π^+)on the x axis and (μ^-, π^-) on the y axis in the signal process (left) and background processes of soft QCD (right)

Distribution of μ+ and μ- by polar angle

Chosen cut: $\left|\cos\left(\theta_{+}\right)\right|^{2}+\left|\cos\left(\theta_{-}\right)\right|^{2}\leq 1.81$

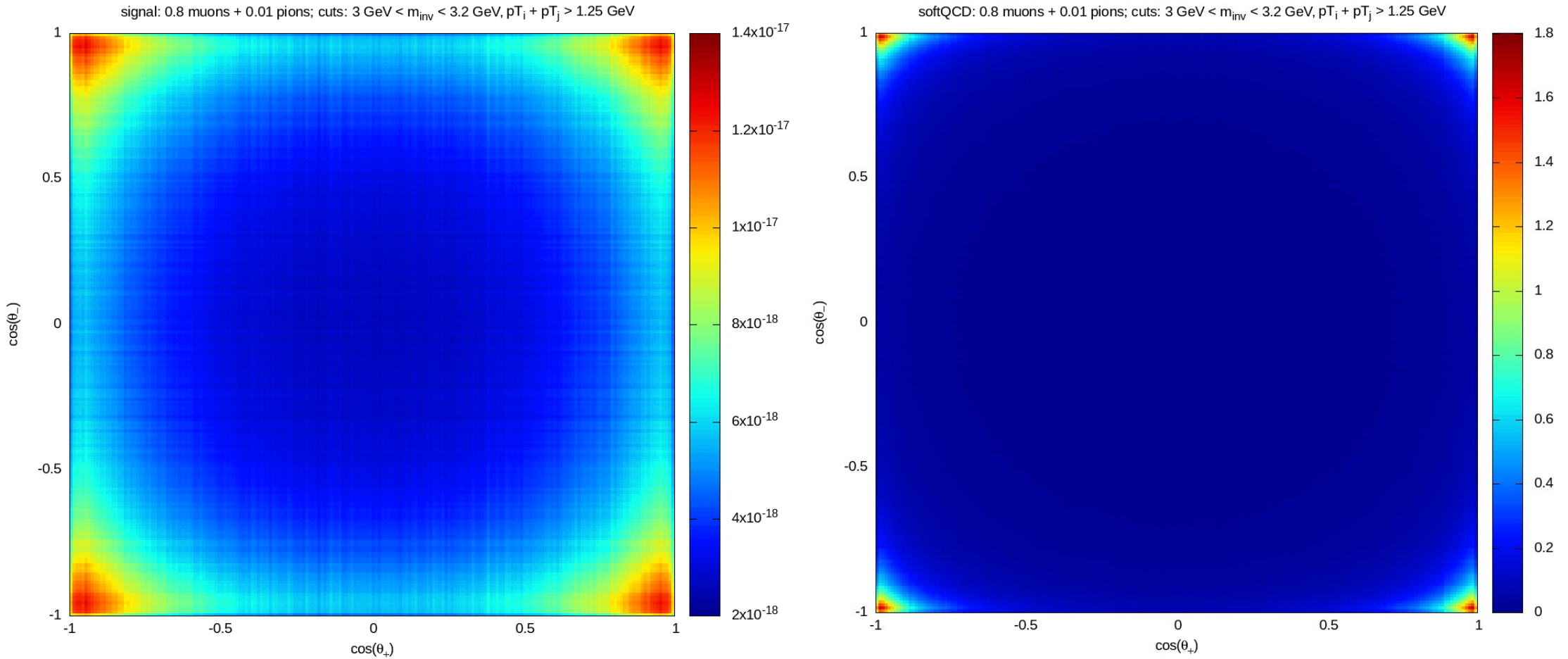


Fig. 3: J/ψ candidates distribution by (cos(θ)) of their forming $\left(\mu^{+},\pi^{+}\right)$on the x axis and $\left(\mu^{-},\pi^{-}\right)$ on the y axis in the signal process (left) and background processes of soft QCD (right).

Chosen cut: $p_+ + p_- > 2.9\,\mathrm{GeV}$

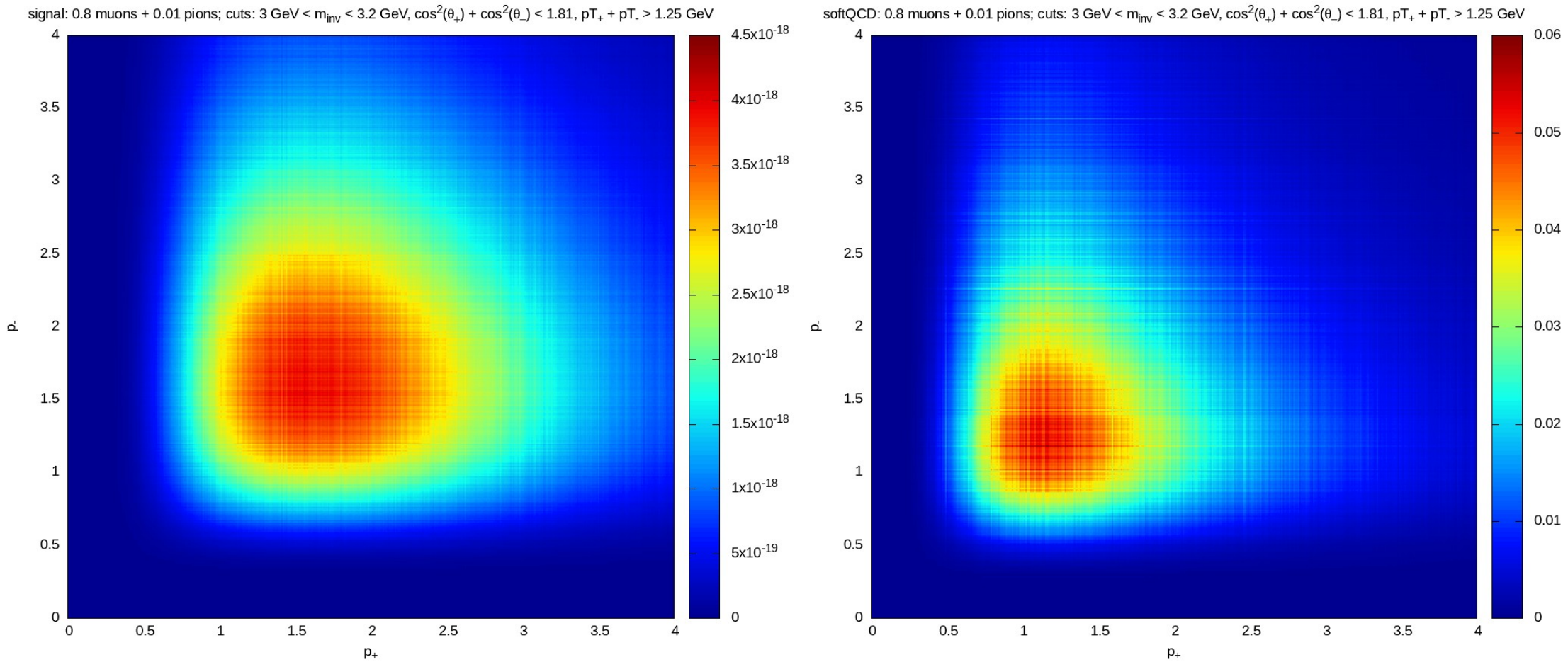


Fig. 4: J/ψ candidates distribution by (p) of their forming (μ^+, π^+) on the x axis and (μ^-, π^-) on the y axis in the signal process (left) and background processes of soft QCD (right).

Distribution of μ+ and μ- by rapidity

Chosen cut: $|y_+| \leq 1.1 ; |y_-| \leq 1.1$

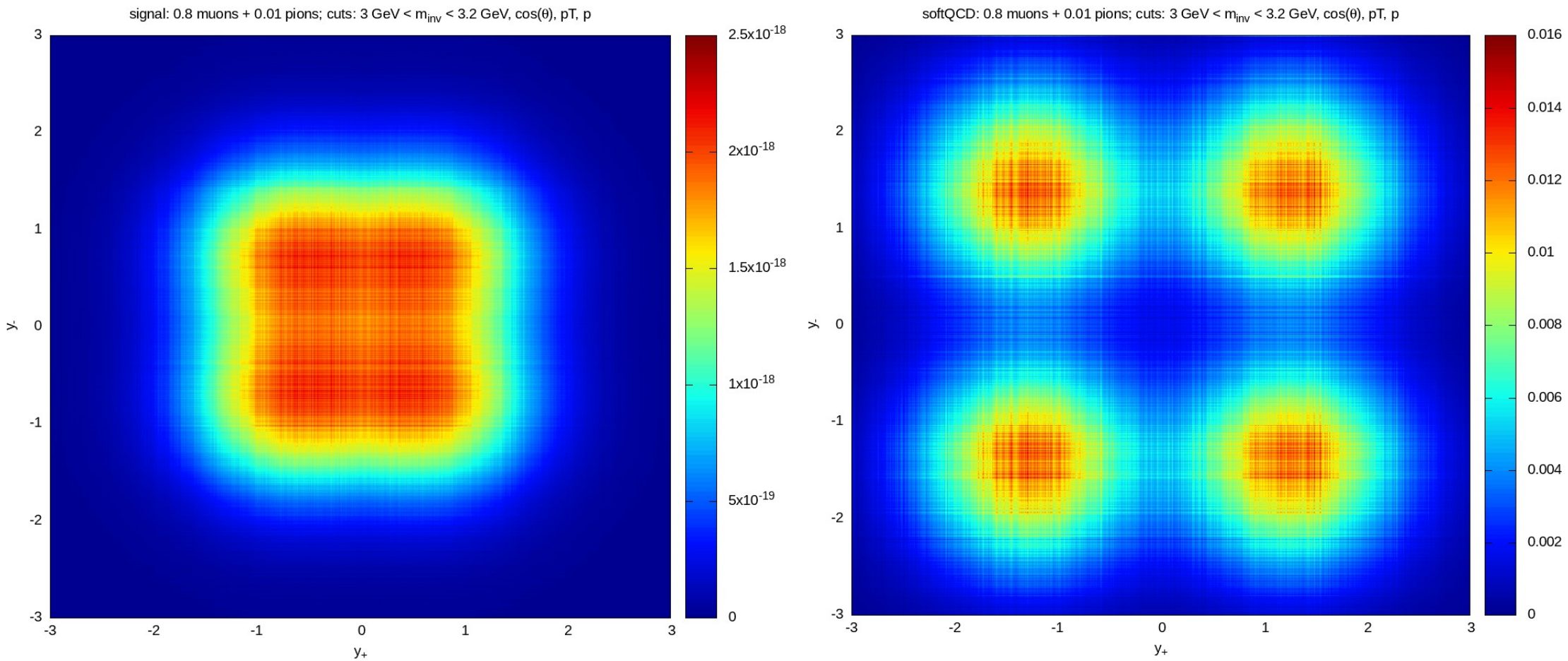
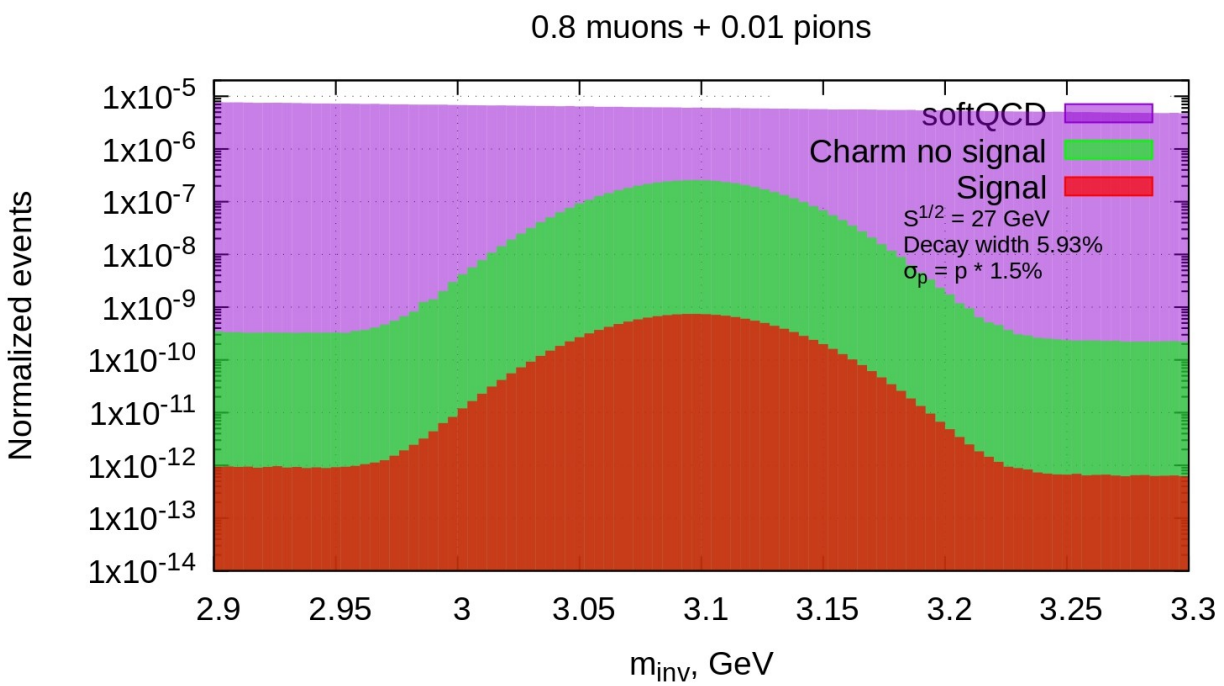


Fig. 5: J/ψ candidates distribution by (y) of their forming (μ^+, π^+) on the x axis and (μ^-, π^-) on the y axis in the signal process (left) and background processes of soft QCD (right).

Efficiency of cuts at 27 GeV

Gain in the signal peak area (m_{inv} = 3.096 GeV): 42.66 times



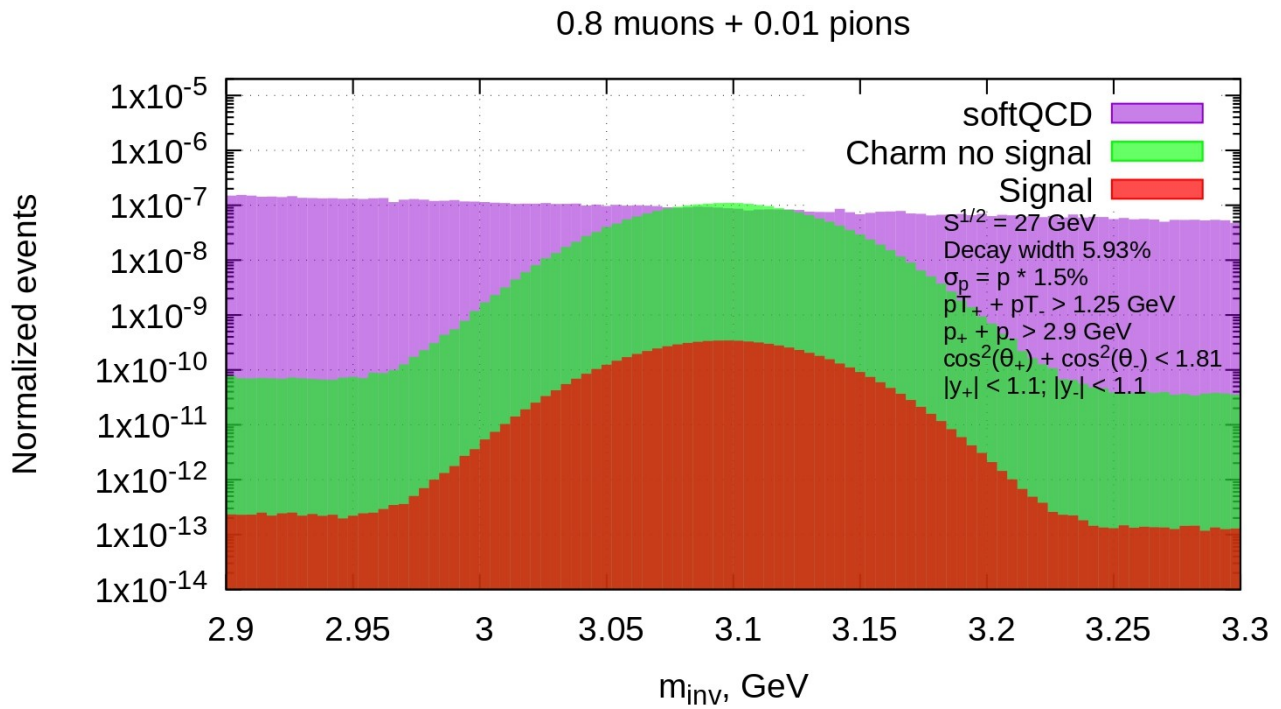


Fig. 6: Histogram of the distribution of the number of candidates in J/ψ mesons by invariant mass without cuts on kinematic parameters (left) and with cuts (right).

Gain in the signal peak area (m_{inv} = 3.096 GeV): 37.21 times

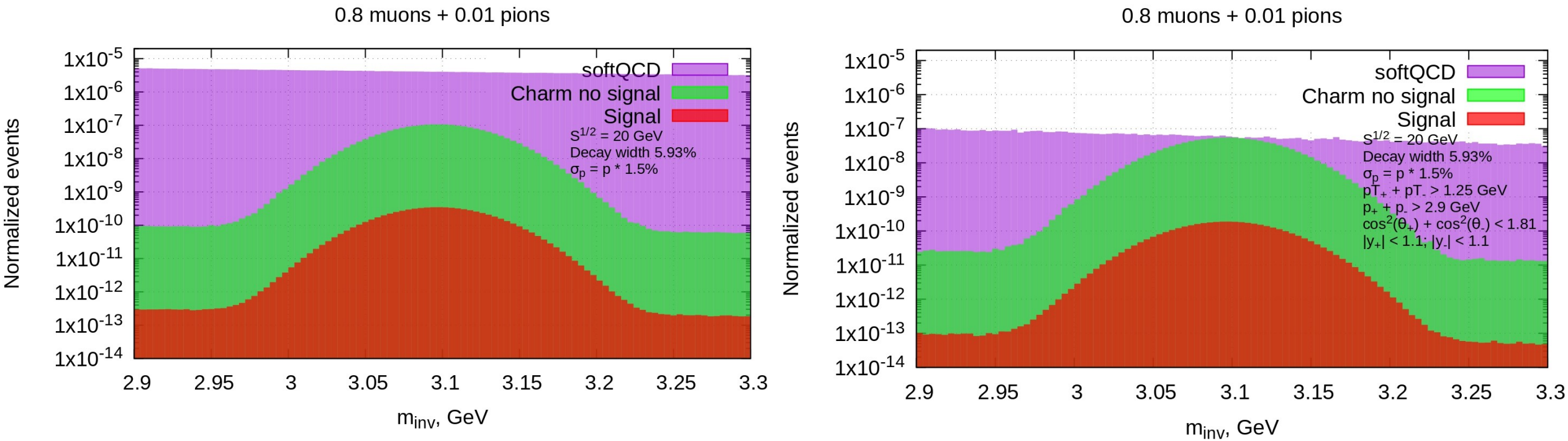


Fig. 7: Histogram of the distribution of the number of candidates in J/ψ mesons by invariant mass without cuts on kinematic parameters (left) and with cuts (right).

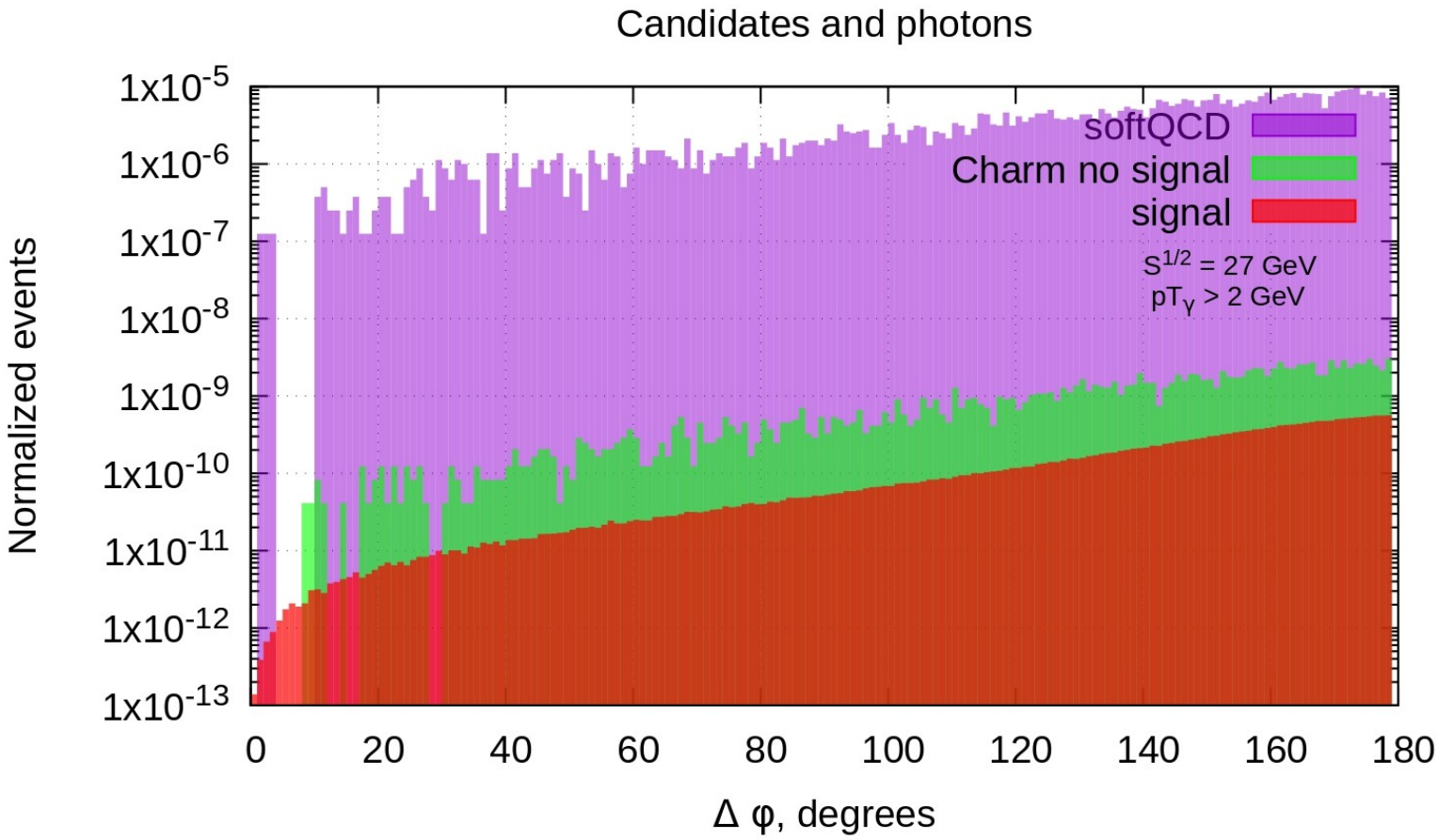
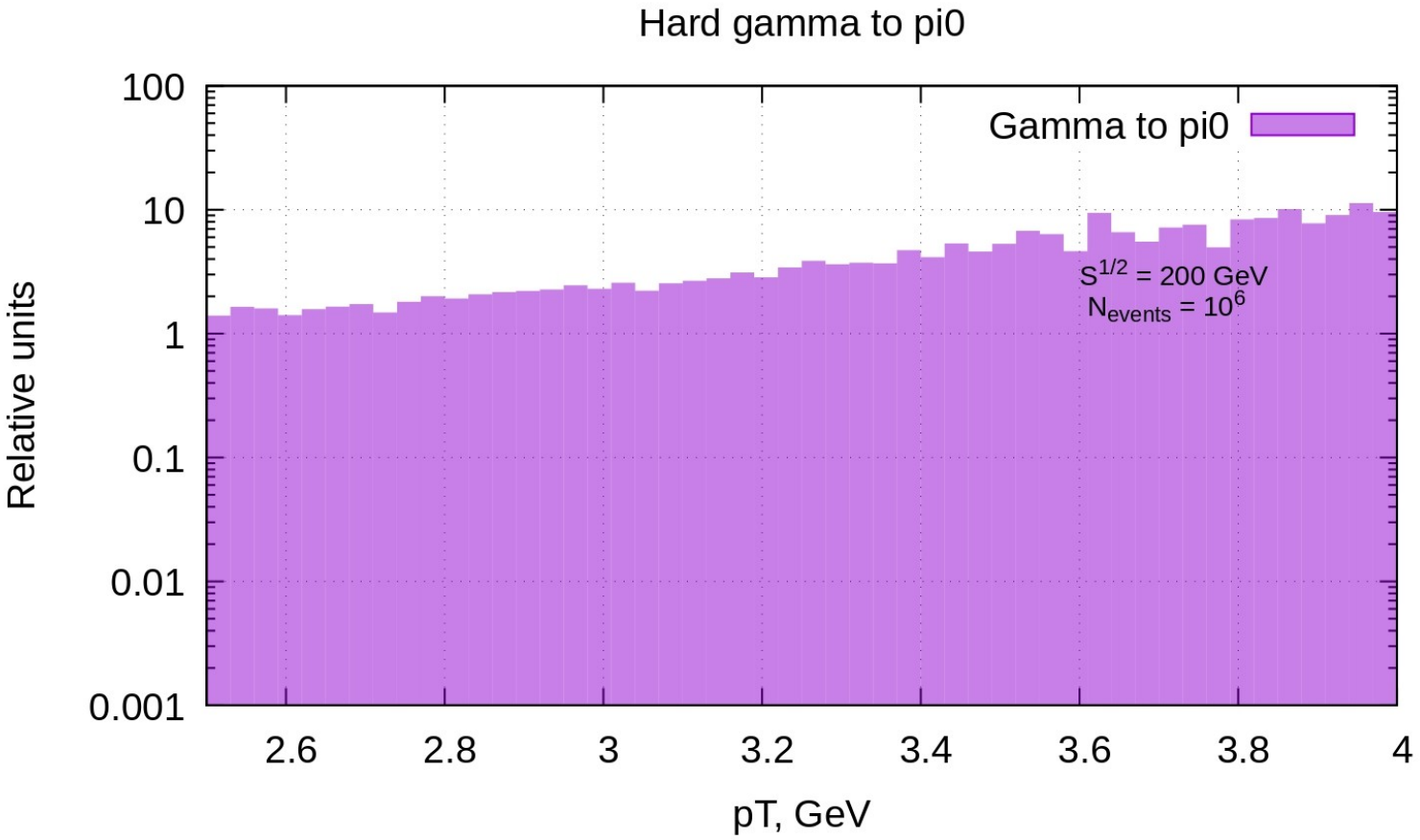


Fig. 8: Histogram of azimuthal angle distribution between J/psi candidates and photons



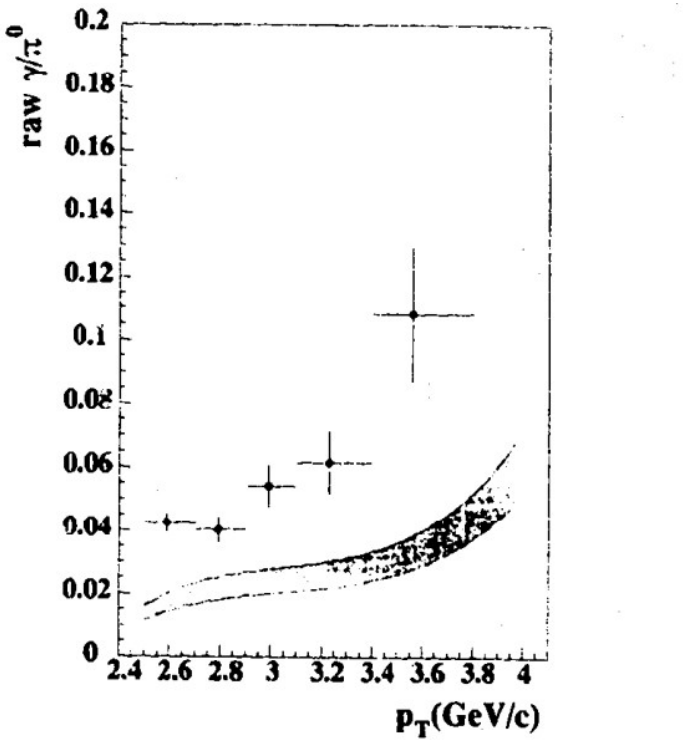


Fig. 3. Ratio of the number of direct photon candidates to the number of π^0's as a function of p_T. Shaded area shows the estimated background.

Fig. 9: Histogram of the ratio of the number of photons to the number of π^0 mesons in the preliminary modeling (left) and in the article “Measurement of single spin asymmetry for direct photon production in pp collisions at 200 GeV/c“ (right).

Conclusion:
Detailed distributions of candidates for J/ψ mesons have been obtained for various kinematic variables when considering the $\mu^+ \mu^-$ mode of J/ψ decay, taking into account the sensitivity of a real detector, in proton-proton collisions at an energy of $\sqrt{s}=27$ GeV in the center-of-mass system.
Based on the distributions obtained, a number of cuts for the selection of signal events were developed. The developed criteria made it possible to increase the ratio of the number of signal events to background ones in the signal peak region by 42.20 times at an energy of $\sqrt{s}=27$ GeV, by 37.21 times at $\sqrt{s}=20$ GeV.

Next goals:
1. Study of azimuthal angle distributions between J/ψ candidates and photons.
2. Study of the contribution of π^0 mesons to the background of direct photons.
   2.1. Modeling the ratio of the number of photons to the number of π^0 mesons in background processes.
   2.2. Development of constraints for cutting background photons from direct ones at the generator level.
   2.3. Comparison with theoretical predictions.

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Thank you for your attention