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# ASSOCIATE J/Ψ MESON AND PHOTON PRODUCTION IN THE ATLAS EXPERIMENT AT THE CERN LHC COLLIDER

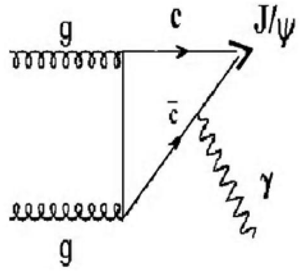
The determination of gluon structure function in the ATLAS experiment using the associate productions of isolated direct prompt photon and s-wave vector states J/Ψ meson is studied in proton-proton collisions at the CERN LHC energies $\sqrt{S} = 14Tev$.

This paper presents a calculation the differential cross section for the production with a high transverse momentum of $J/\Psi$ $(J^{pc} = 1^{--})$ meson accompanied by the hard photon at the CERN in Large Hadron Collider pp collisions at $\sqrt{s} = 14Tev$:

$$p + p \rightarrow J/\Psi + \gamma + X.$$

Previous studies of this reaction was at $\sqrt{s} = 1.8Tev$ [1] and in case of polarized particles [2]. Leading order (LO) calculations of prompt photon and charm production were carried out to constrain the charm content of the proton [3].

In LO a J/Ψ meson and photon final state with high transverse momentums can only be produced by QCD gluon fusion $g + g \rightarrow J/\Psi + \gamma$.




Note that e.g. the reaction $g + g \rightarrow \chi_c \rightarrow$ $\rightarrow J/\Psi + \gamma$ produce photons with small transverse momentum and $g + g \rightarrow \chi_c + \gamma$ is not possible. The interpretation of any observed signal should therefore be considerably simpler either for inclusive direct photon production [4] (QCD compton process $qg \rightarrow q\gamma$ and the annihilation graphs), inclusive charm production [5] (compton scattering off a charm sea quark $gc \rightarrow gc$, from b-quark decays, gluon splitting and so on) as well as for other reactions of a photon production in association with charm at the next-to-leading order (NLO) ($gc \rightarrow \gamma gc$ and so on), where several initial states can lead to essentially the same final state. In our case the final state particles with sizeable transverse momentum are photon and leptons (from J/Ψ decay into $e^+e^-$ or $\mu^+\mu^-$), whose energies and momentums can be measured with high precision, so such events can be fully reconstructed. The cleanliness of this signal should also guarantee that instrumental backgrounds are small. So the direct photon, balanced by charged leptons pair in the opposite hemisphere, is a clean probe of the gluon distribution.

The cross section can be obtained from a LO calculation using PYTHIA, including a simulation of the detector response (using ATLFAST). The differential cross section is given by:

$$E\frac{d\sigma}{d^3p} = \sum \int dx_a\, dx_b\, \frac{dz}{z^2} f(x_a, M_f^2) \times$$

$$\times f(x_b, M_f^2) D(z, M_D^2) \left( E\frac{d\hat{\sigma}}{d^3p} \right).$$

Here

$$E\frac{d\hat{\sigma}}{d^3p} = \frac{\hat{s}}{\pi}\frac{d\hat{\sigma}}{d\hat{t}}\delta(\hat{s} + \hat{u} + \hat{t})$$

$$\delta(\hat{s} + \hat{u} + \hat{t}) = \frac{z}{\hat{s}}\, \delta\left( z - \frac{x - x_f}{2x_b} - \frac{x + x_f}{2x_a} \right),$$

$$\hat{s} = x_a x_b S;\ \hat{t} = \frac{x_a}{z}T = \frac{x_a}{z}\left( -\frac{S}{2}(x - x_f) \right)$$

$$\hat{u} = \frac{x_b}{z}U;\ U = -\frac{S}{2}(x + x_f);\ x = \sqrt{x_f^2 + x_t^2},$$

where $x_f = 2p_f/\sqrt{s}$, $x_t = 2p_t/\sqrt{s}$, here $x_f, x_t$ are the longitudinal and transverse momentum fraction and S, T, U – are the Mandelstam variables.

Neglecting the binding energy (J/Ψ meson as S-wave $c\bar{c}$ system) and using the so-called colour singlet model (colourless of gg condition and for fragmentation: z=1, D(z)=1) for the partonic cross section $\hat{\sigma}$ we have [6]:

$$\frac{d\hat{\sigma}}{d\hat{t}}(g+g\to\psi+\gamma)=\frac{16\pi\alpha\alpha_s^2 m_\psi (R(0))^2}{27\hat{s}^2}\times$$

$$\times\left\{\left((1+\lambda_1\lambda_2)\frac{\hat{s}^2}{(\hat{t}-m_\psi^2)^2(\hat{u}-m_\psi^2)^2}\right)+\right.$$

$$+(1-\lambda_1\lambda_2)\left[\frac{\hat{t}^2}{(\hat{u}^2-m_\psi{}^2)^2(\hat{s}^2-m_\psi{}^2)^2}+\right.$$

$$\left.\left.\frac{\hat{u}^2}{(\hat{s}-m^2{}_\psi)^2(\hat{t}-m_\psi^2)^2}\right]\right\},$$

where $\lambda_{1(2)}$ is the helicity of the initial partons and $c\bar{c}$ wave function at origin $|R(0)|^2$

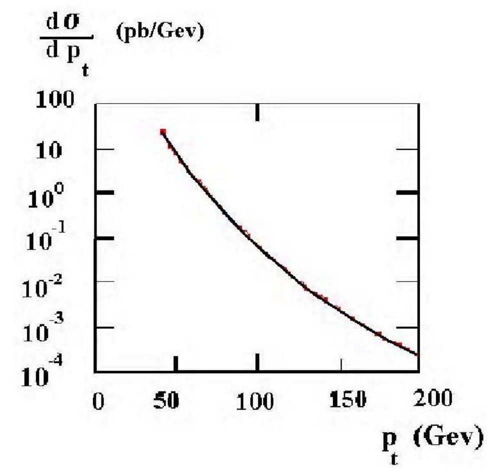
$$|R(0)|^2=\Gamma_{e^+e^-}\frac{9m_\psi^2}{16\alpha^2}=0.48\ Gev^2,$$

where $m_\Psi$=3.1Gev is the mass of J/Ψ meson and $\Gamma_{e^+e^-}$ is the leptonic decay width of J/Ψ including QCD radioactive corrections. Since higher order QCD corrections have not yet been computed we use leading order expressions.

We choose the gluon distribution function [7] and use the one-loop expression for the QCD running coupling $\alpha_s$ with $N_f$=6 active flavors and $\Lambda_{QCD}=200Mev$. The cross section is insensitive to choice of $Q^2$ ($m_\psi^2+p_t^2, 4p_t^2, \sqrt{\hat{s}\hat{t}\hat{u}}\ or\ \hat{s}$) for each type of gluon density so we take $Q^2=m_\psi^2+p_t^2$ as a momentum scale both in $\alpha_s$ and in structure function. The difference between a LO and a NLO (next-to-leading order) is quantified in the K-factor, which is defined as the ratio between the cross section at NLO to the one at LO. From an analytical NLO calculation one can indicate K-factor, which we take in the form $K=1+C\alpha_s(Q^2)$.

The associated production of a J/Ψ meson at the LHC, together with a photon, should not be dominated by fragmentation contributions up to $p_t$ values of 50 Gev [8]. This should be due to the fact that $q\bar{q}$ initial states are suppressed at the CERN LHC. We use the cuts: $p_t \geq 40\ Gev$. The method to extract the gluon structure function can be based on fitting the $J/\Psi-\gamma$ cross section to the predictions. A further possibility is the associated study of the production of J/Ψ mesons with a W or Z boson, as discussed in [9], which can be used to cross-check the predictions of colour octet model.

The transverse momentum spectrum of the photon are shown in the figure:

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**Резюме**

АТЛАС экспериментінде LHC энергиясында ($\sqrt{s} = 14\ Tev$) J/Y мезон мен фотонның бірлесіп тууында глюонды құрылымдық функцияны анықтау зерттелген.

**Резюме**

Исследуется определение глюонной структурной функции в ассоциативном рождении J/Ψ мезона и фотона в эксперименте ATLAS при энергии LHC ($\sqrt{s} = 14\ Tev$).

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