Search for intrinsic charm contribution in proton from open and hidden charm particle production in pp collisions

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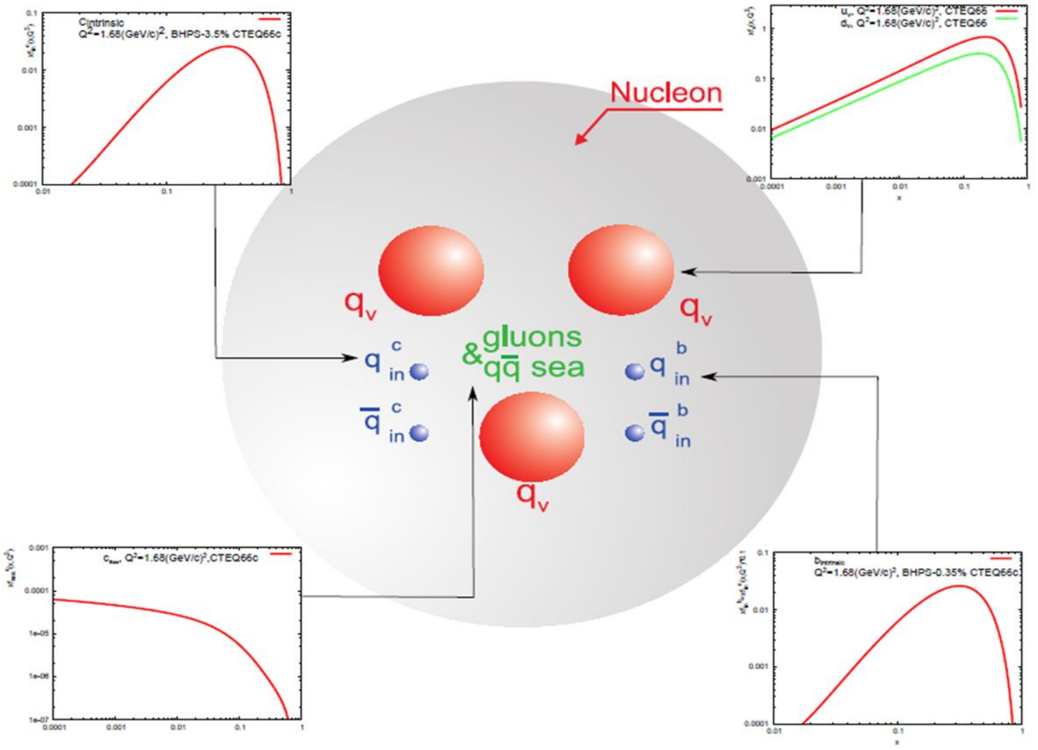
JINR, Dubna

BHPS model: S.J. Brodsky,P. Hoyer, C. Peterson and N.Sakai, Phys.Lett.B9(1980) 451; S.J. Brodsky, S.J. Peterson and N. Sakai, Phys.Rev. D23 (1981) 2745.

Intrinsic $Q\bar{Q}$ in proton



INTRINSIC HEAVY QUARK STATES

Two types of parton contributions

The extrinsic quarks and gluons are generated on a short time scale in association with a large transverse-momentum reaction.

The intrinsic quarks and gluons exist over a time scale independent of any probe momentum, they are associated with the bound state hadron dynamics.

$$P(x_1,\ldots,x_5)=N_5\,\delta\left(1-\sum_{i=1}^{5}x_i\right)\left[M_p^2-\sum_{i=1}^{5}\frac{m_i^2}{x_i}\right]^{-2}$$

INTRINSIC HEAVY QUARK DISTRIBUTION IN PROTON

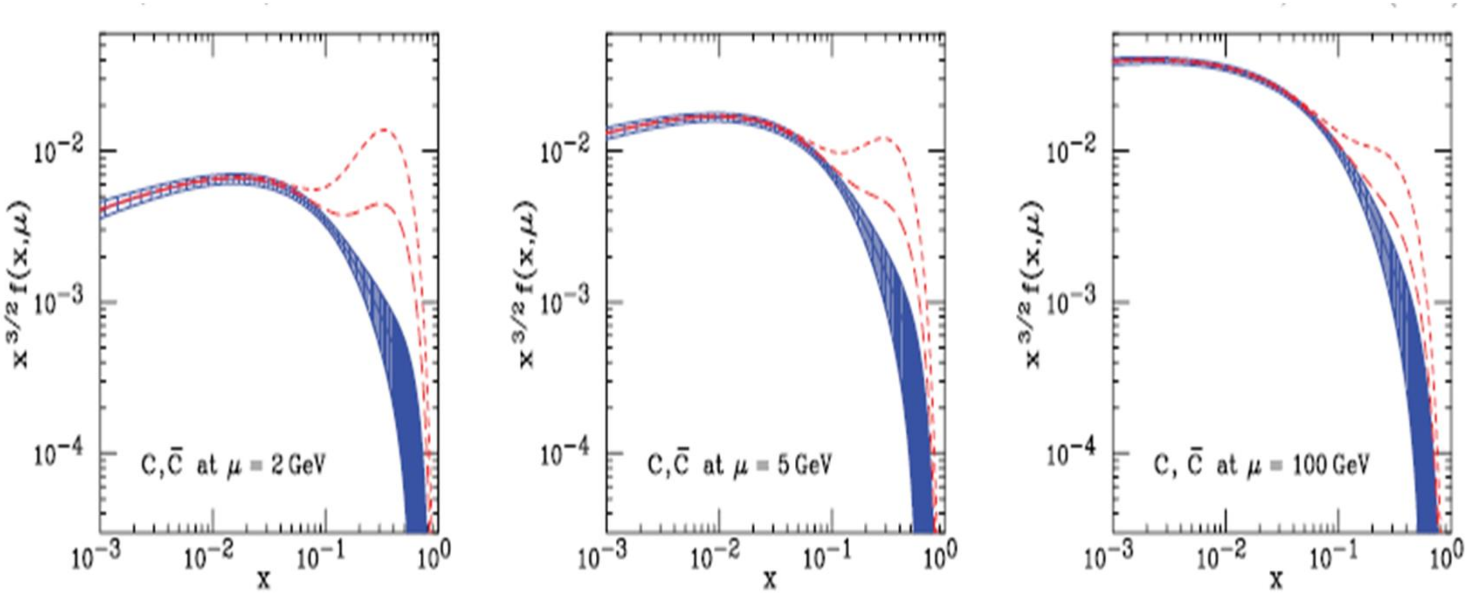
Integrating $P(x_1,\ldots,x_5)$ over $dx_1\ldots dx_4$ and neglecting of all quark masses except the charm quark mass we get

$$P(x_5)=\frac{1}{2}\overline{N}_5 x_5^2\left[\frac{1}{3}(1-x_5)(1+10x_5+x_5^2)+2x_5(1+x_5)\ln\left(1/x_5\right)\right]$$

Where $\overline{N}_5 = N_5 / m_{4,5}^4$ normalization constant . Here $m_4 = m_5 = m_c = m_{\bar{c}}$ is the bar mass of the charmed quark. N_5 determines some probability w_{IQ} to find the Fock state $|uudQ\overline{Q}\rangle$ in the proton.

One can see qualitatively that $P(x_5)$ **vanishes at** $x_5 \to 0$ **and** $x_5 \to 1$ **and has an enhancement at** $0 < x_5 < 1$

CHARM QUARK DISTRIBUTIONS IN PROTON



Charm quark distributions within the BHPS model. The three panels correspond to the renormalization scales $\mu = 2,5,100$ GeV respectively. The long-dashed and the short-dashed curves correspond to $\langle x_{c\bar{c}} \rangle = 0.57\%, 2.\%$ respectively using the PDF CTEQ66c. The solid curve and shaded region show the central value and uncertainty from CTEQ6.5, which contains no ***IC***.

There is an enhancement at x>0.1 due to the IC contribution

PRODUCTION OF HEAVY FLAVOURS IN HARD P-P COLLISIONS

$$E\frac{d\sigma}{d^3p} = \sum_{i.i}\int d^2k_{iT}\int d^2k_{jT}\int_{x_i^{\min}}^{1} dx_i \int_{x_j^{\min}}^{1} dx_j f_i(x_i,k_{iT}) f_j(x_j,k_{jT}) \frac{d\sigma_{ij}(\hat{s},\hat{t})}{d\hat{t}} \frac{D_{i,j}^{h}(z_h)}{\pi z_h}$$

$$x_i^{\min} = \frac{x_T \cot(\frac{\theta}{2})}{2 - x_T \tan(\frac{\theta}{2})} \qquad x_F \equiv \frac{2p_z}{\sqrt{s}} = \frac{2p_T}{\sqrt{s}}\frac{1}{\tan\theta} = \frac{2p_T}{\sqrt{s}}\sinh(\eta)$$

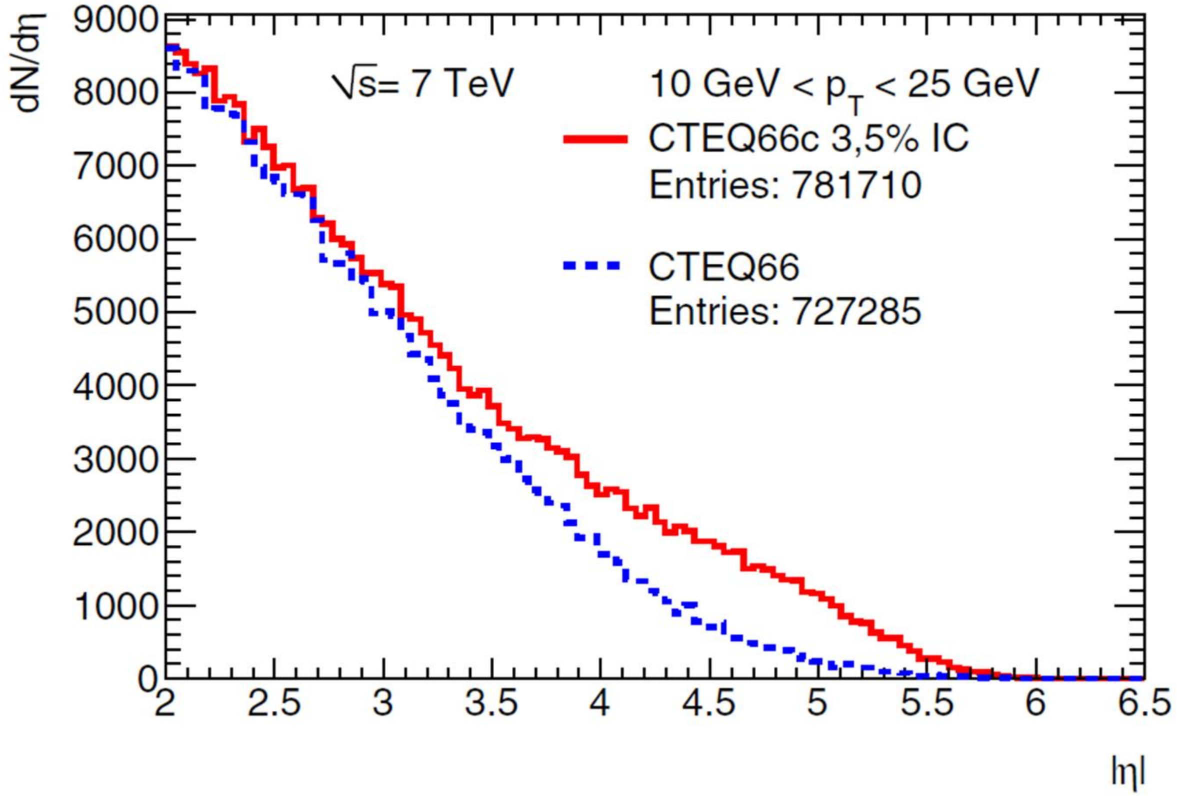
$$x_i^{min} = \frac{x_R + x_F}{2 - (x_R - x_F)} \qquad x_R = 2p/\sqrt{s}$$

One can see that $x_i \geq x_F$ If $x_F > 0.1$ then, $x_i > 0.1$ and the conventional sea heavy quark (extrinsic) contributions are suppressed in comparison to the intrinsic ones.

x_F is related to p_h and η . So, at certain values of these variables, in fact, there is no conventional sea heavy quark (extrinsic) contribution. And we can study the IQ contributions in hard processes at the certain kinematical region.

$x_F = 2p_T sh(\eta)/s^{1/2}$ → **IC signal can be visible at** $p_T > x_F s^{1/2} /(2sh(\eta))$

PP -> $D_0 + \overline{D_0} + X$, $s^{1/2} = 7$ TeV



The $D_0 + \overline{D_0}$ distribution as a function of the pseudo-rapidity |η|. Blue line is the spectrum without *IC* and red curve corresponds to the *IC* probability about 3.5%.

G.L., V.A.Bednyakov, A.F. Pikelner, N.I.Zimine, Europhys.Lett.,99, p. 21002 (2012). S.J.Brodsky, V.A.Bednyakov, G.L., J.Smiesko, S.Tokar, Progr.Part.Nucl.Phys., 93, p.108 (2017).

PRODUCTION of J/ψ - MESON IN PP at NICA

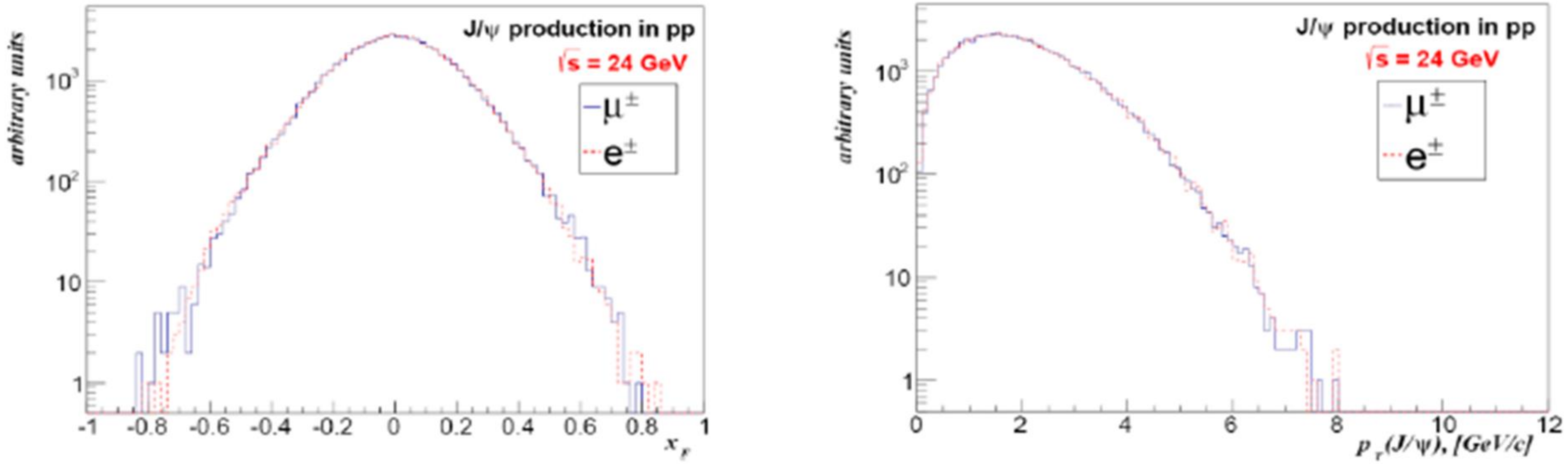


Fig. 5.8: Distributions of directly produced J/Ψ vs. x_F (left) and vs. p_T (right).

pp -> J/ψ +X at NICA, $s^{1/2} = 24$ GeV.

$x_F = 2p_T\,\mathrm{sh}(\eta)/s^{1/2}$ IC signal in the spectrum $E d\sigma/d^3p$ can be visible at $x_c > x_F \sim 0.1$ or at $p_T > 0.1\, s^{1/2}/(2\mathrm{sh}(\eta))$. If $p_T \sim 1.5$-2 GeV/c, then $\eta > 0.57 - 0.73$. The maximum value of IC signal can be visible at $\eta \sim 1.35 – 1.88$

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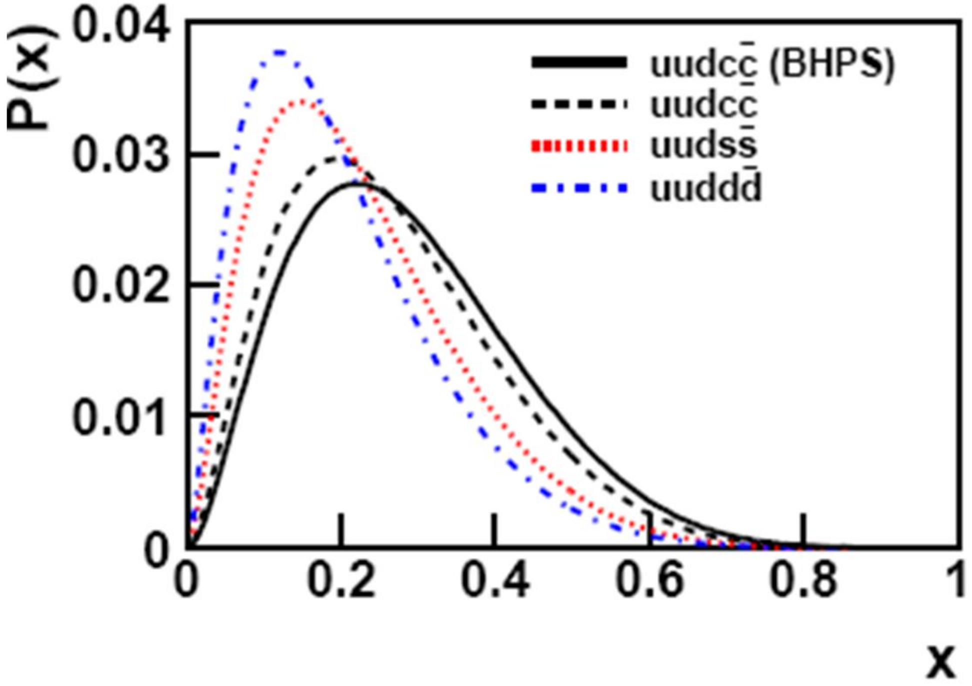
SUMMARY

1. It is shown that the intrinsic charm contribution in proton can be searching for in hard production of open and hidden charm hadrons in pp collisions.
2. We predict a significant enhancement in the rapidity spectrum of D-mesons produced in pp collisions, which corresponds to a possible existence of intrinsic charm contribution in proton.
3. This *IC* signal can be measured in p_T – spectrum of D-mesons or Λ_c – baryons at NICA.
4. The J/ψ production in pp collisions at NICA can result in a new information on the *IC* contribution in proton.
5. We present the preliminary estimations of kinematical region, where the *IC* signal in p_T – spectrum of J/ψ can be measured at NICA.

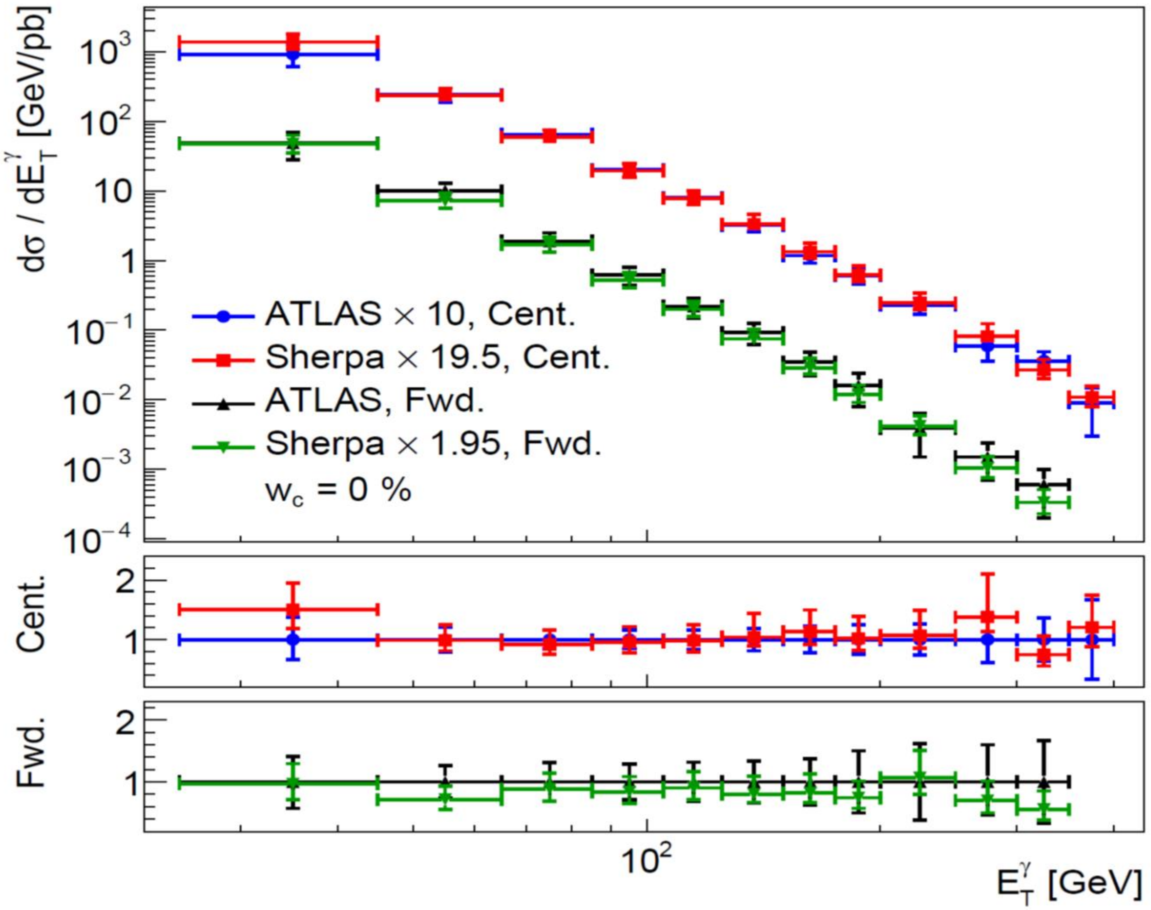
THANK YOU VERY MUCH FOR YOUR ATTENTION !

BACK UP



The x-distribution of the intrinsic **Q** calculated within the BHPS model. **There is an enhancement at x > 0.1**
Jen-Chieh Peng & We-Chen Chang, hep-ph/1207.2193.

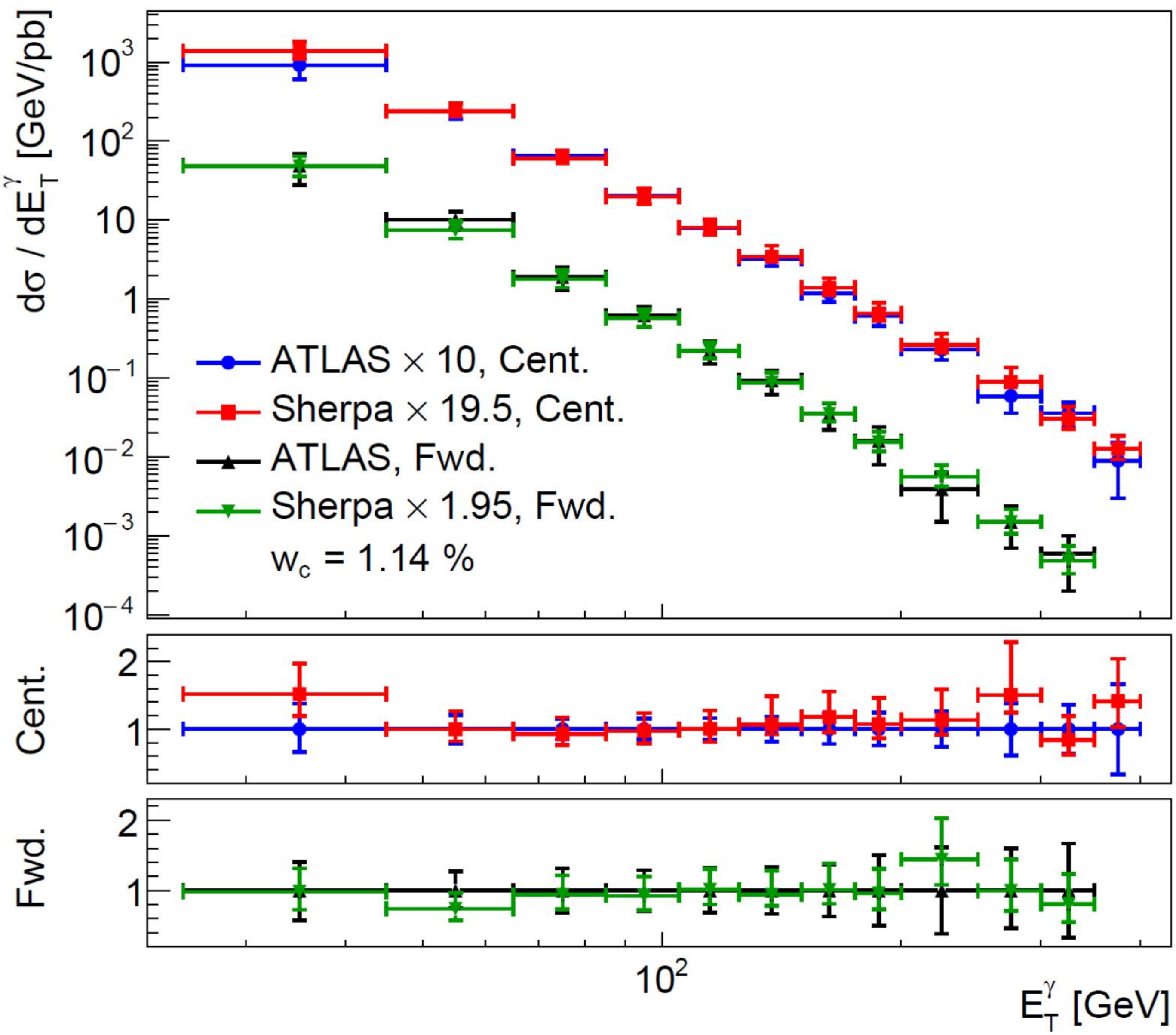
TRANNSVERSE ENERGY SPECTRUM OF PHOTONS PRODUCED in P-P AT $S^{1/2}$ =8 TeV



(a) $w_c = 0\%$

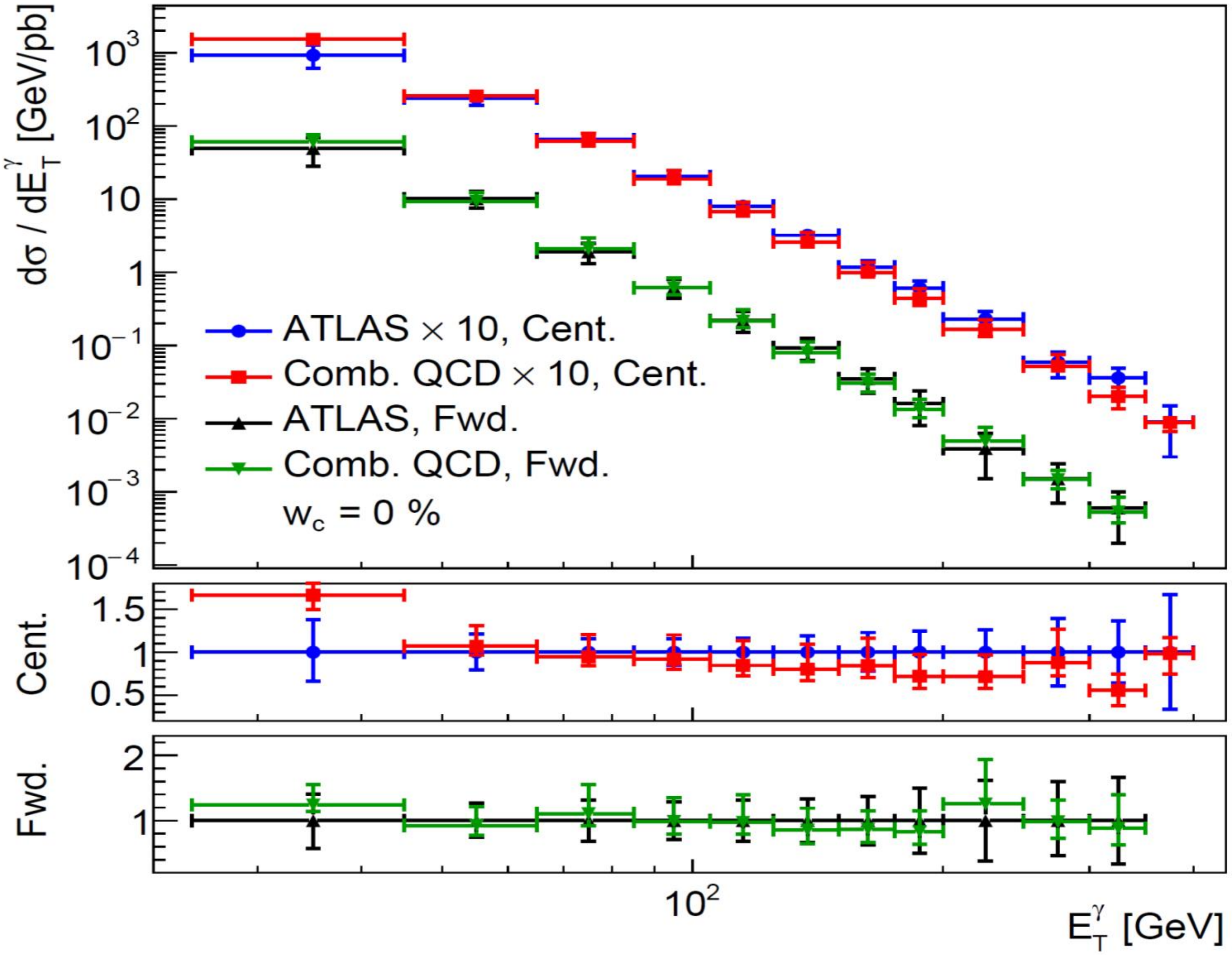
ArXiv: 1712.09096 [hep-ph], December 1917

Central: |η| <1.37; Forward: 1.56<|η|<2.37; w_c is the IC probability


dσ / dE$_T^\gamma$ [GeV/pb]
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
ATLAS × 10, Cent.
Sherpa × 19.5, Cent.
ATLAS, Fwd.
Sherpa × 1.95, Fwd.
w$_c$ = 1.14 %
Cent.
2
1
Fwd.
2
1
10^2
E$_T^\gamma$ [GeV]

(b) $w_c = 1.14\%$

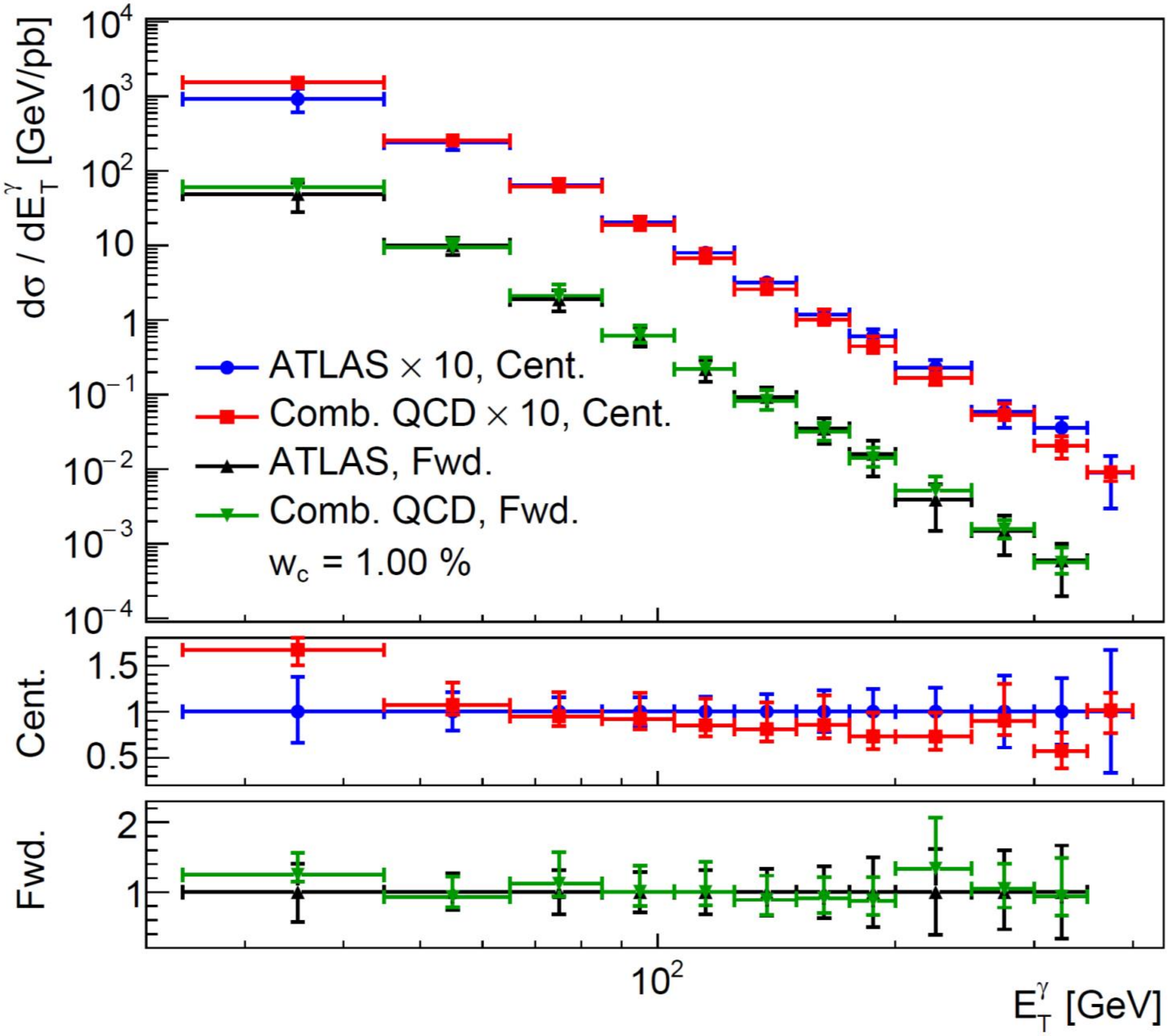
TRANNSVERSE ENERGY SPECTRUM OF PHOTONS PRODUCED in P-P AT $S^{1/2}$ =8 TeV



(a) $w_c = 0\%$

Combined QCD is k_T – factorization for $c+g^*$ ->ɤ + c and $g^* + g^* + c + \bar{c}$

and conventional collinear QCD for quarks and antiquarks graphs.



(b) $w_{\mathrm{c}} = 1.00\%$

	SHERPA [%]	Comb. QCD [%]
w_{c}	1.14	1.00
$w_{\mathrm{u.\,l.}}$ (68% C.L.)	2.74	3.69
$w_{\mathrm{u.\,l.}}$ (90% C.L.)	3.77	6.36
$w_{\mathrm{u.\,l.}}$ (95% C.L.)	4.32	> 7.5

TABLE I. Central w_{c} value and upper limits $w_{\mathrm{u.\,l.}}$ obtained within SHERPA and combined QCD calculations.

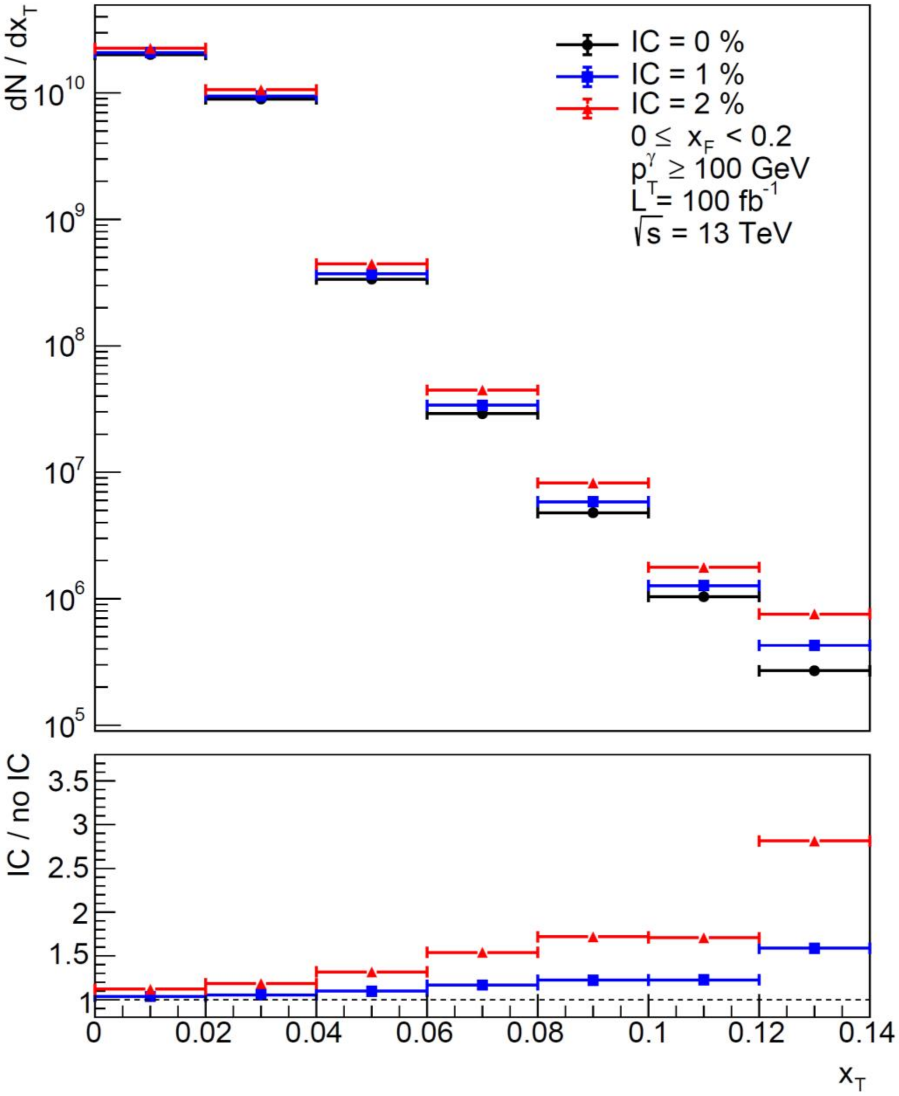
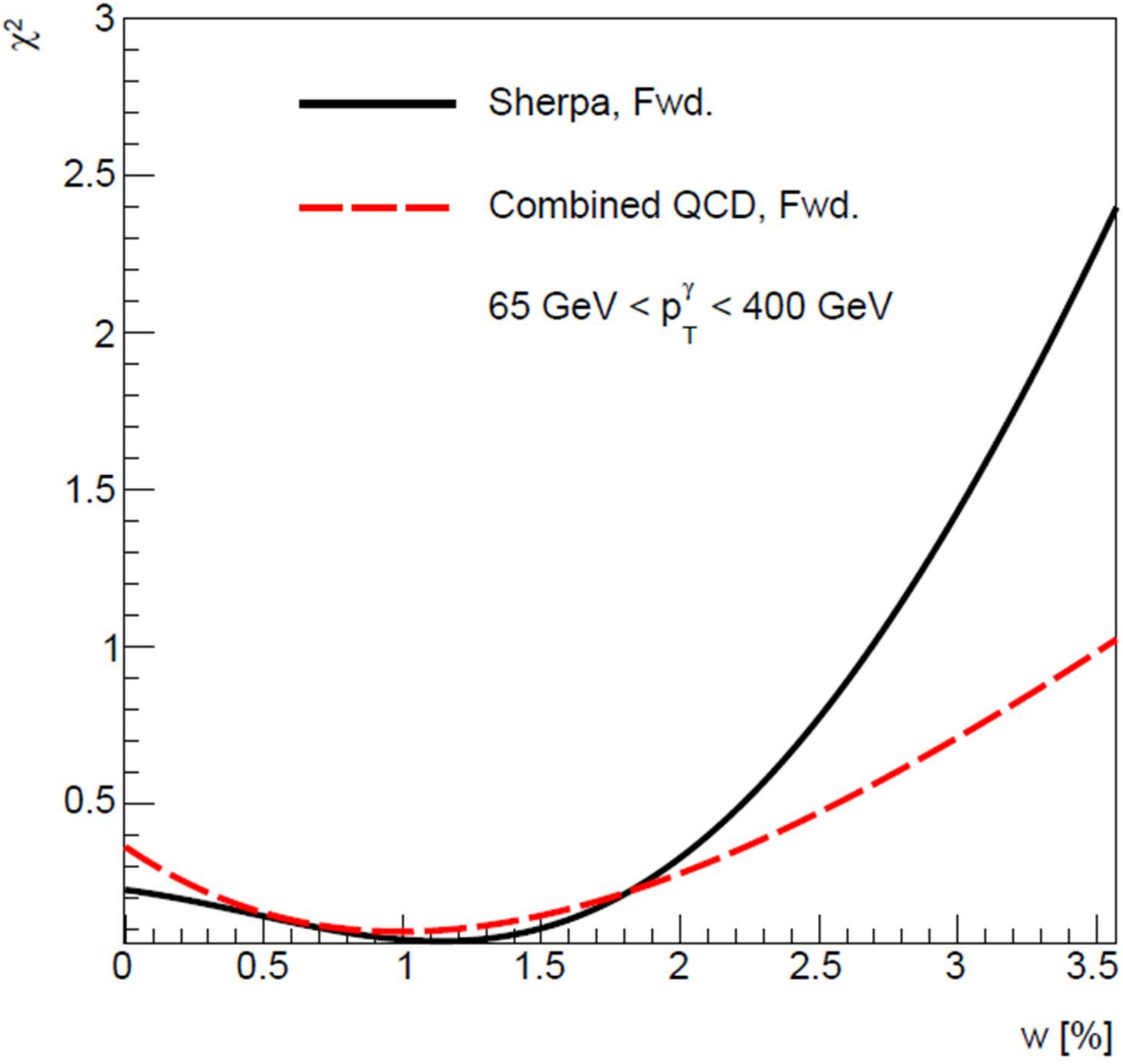
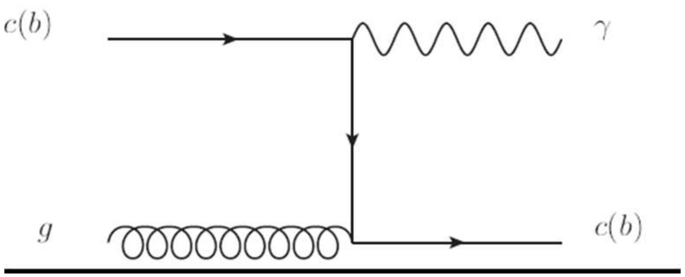


FIG. 4. Top: the distribution of number of prompt photon events as a function of x_{T} calculated within the MC generator SHERPA at $\sqrt{s} = 13$ TeV and different values of the IC probability $w = 0\%$ (circles), $w = 1\%$ (squares) and $w = 2\%$ (triangles). Bottom: the ratio of the MC calculation including the IC contribution and without it.


χ^2
3
2.5
2
1.5
1
0.5
Sherpa, Fwd.
Combined QCD, Fwd.
65 GeV < p_T^γ < 400 GeV
0
0.5
1
1.5
2
2.5
3
3.5
w [%]

PHOTON (DI-LEPTON) AND c(b)-JETS PRODUCTION IN P-P



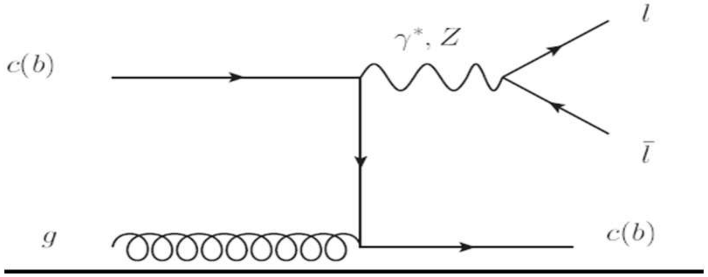


Fig.a. Feynman diagram for the process $c(b)+g\rightarrow\gamma+c(b)$

Fig.b. Feynman graph for the process $c(b)+g\rightarrow\gamma/Z^0+c(b)$

$$x_F = \frac{2\mathrm{p}_T}{s^{1/2}} sh(\eta); \; p_{T\gamma} = -p_{Tc}.$$

$$x_{c(b)} = \frac{m^2_{l^+l^-}}{x_g s} + x^f_{c(b)}$$

To observe the IC

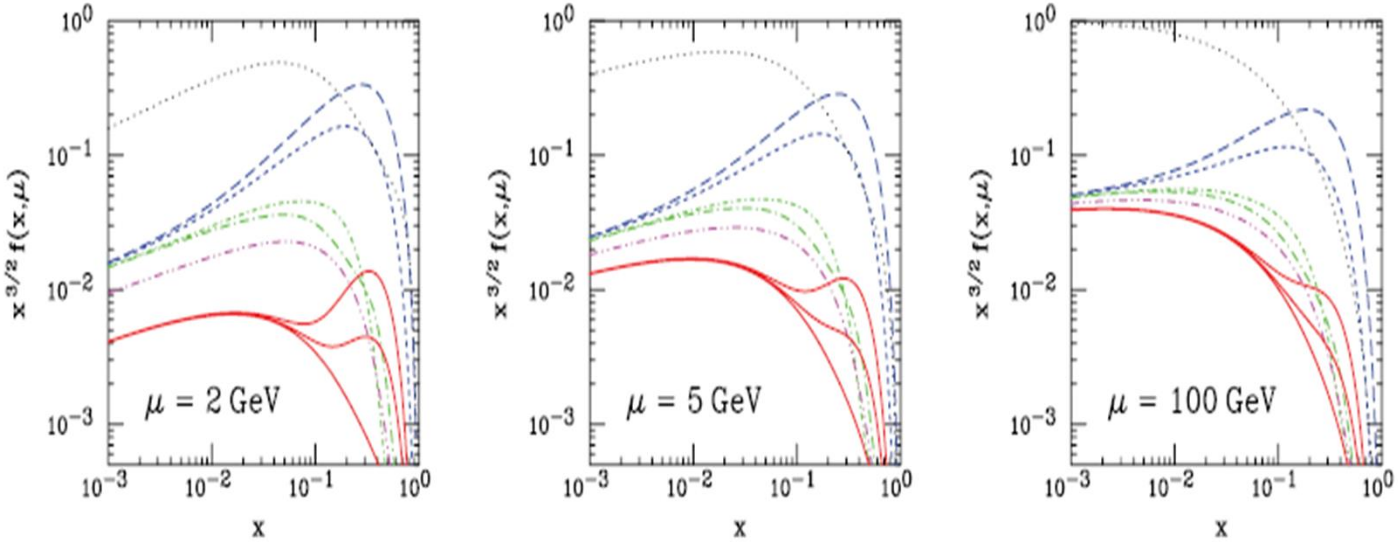
for Fig.a

$$x_c \geq x_F > 0.1$$

for Fig.b

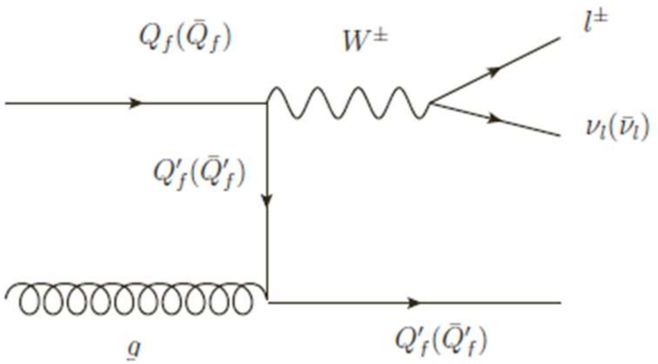
$$x_{c(b)} = \frac{m^2_{l^+l^-}}{x_g s} + x^f_{c(b)} > 0.1$$

COMPARISON OF LIGHT AND HEAVY QUARK DISTRIBUTIONS IN PROTON

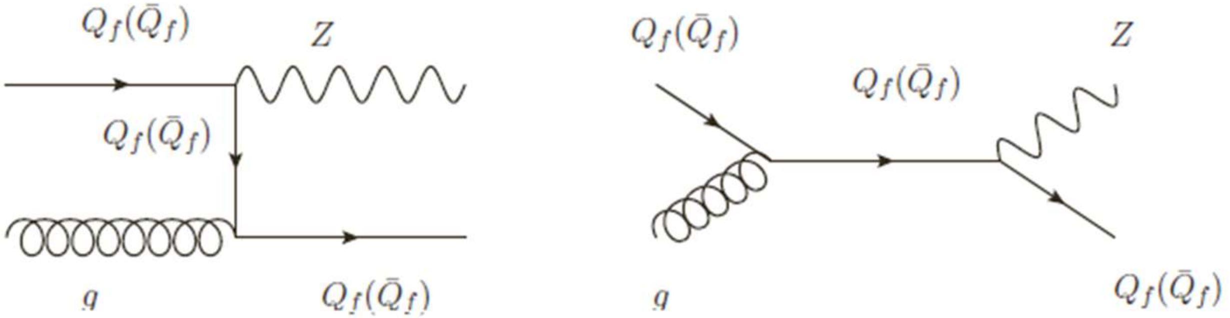


The dotted line is the gluon distribution, the blue long-dashed curve is the valence u-distribution, the blue short-dashed line is the valence d-distribution, the green long-dashed-dotted line is the intrinsic $\bar{u}$, the short dashed-dotted line is the intrinsic $\bar{d}$ distribution, the dashed-dot-dotted is the intrinsic $s=\bar{s}$ and the solid curves are $c=\bar{c}$ with **no IC** (lowest) and with **IC**, $\langle x_{c\bar{c}}\rangle = 0.57\%, 2.\%$ respectively. It is shown that **IC** contribution is larger than $\bar{u}, \bar{d}, \bar{s}$ at x>0.2

pp →W/Z+heavy flavour jets



The LO Feynman diagrams for the process $Q_f(\bar{Q}_f)g \to W^\pm Q'_f(\bar{Q}'_f)$, where $Q_f = c.b$ and $Q'_f = b, c$ respectively.



Feynman diagram for the process $Q_f(\bar{Q}_f)g \to ZQ_f(\bar{Q}_f)$