Constraints on the intrinsic charm contribution to PDF from ATLAS data

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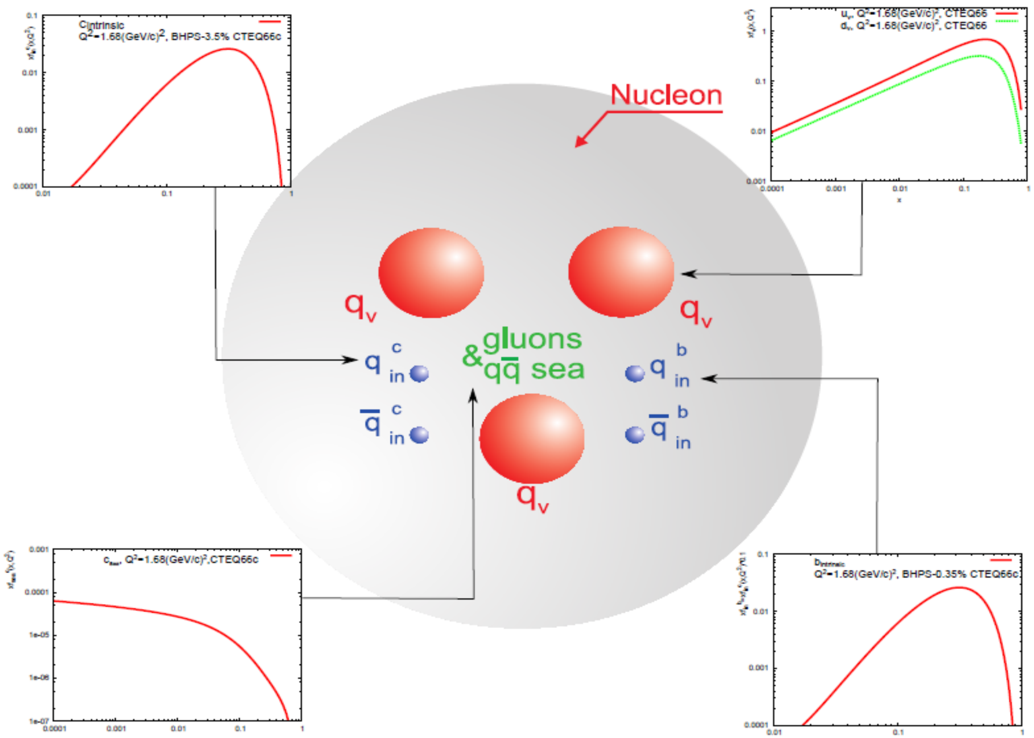
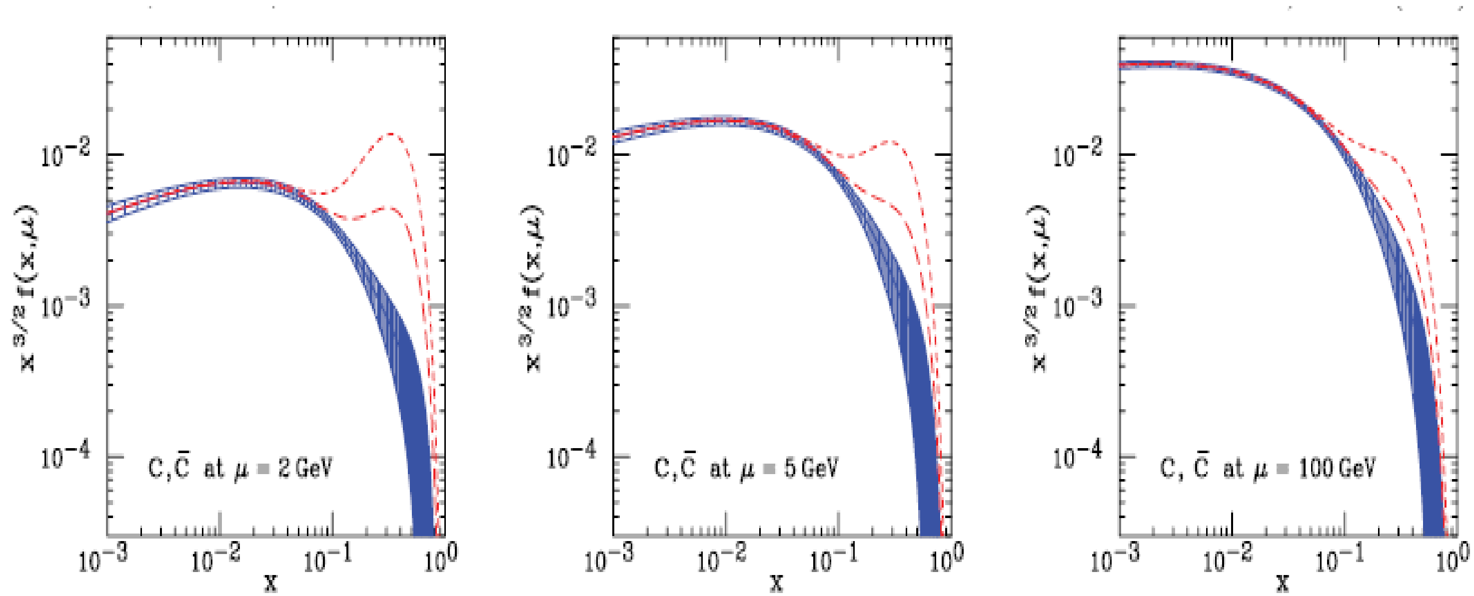
BHPS model: S.J. Brodsky,P. Hoyer, C. Peterson and N.Sakai, Phys.Lett.B9(1980) 451; S.J. Brodsky, S.J. Peterson and N. Sakai, Phys.Rev. D23 (1981) 2745.

Intrinsic $Q\bar{Q}$ in proton



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

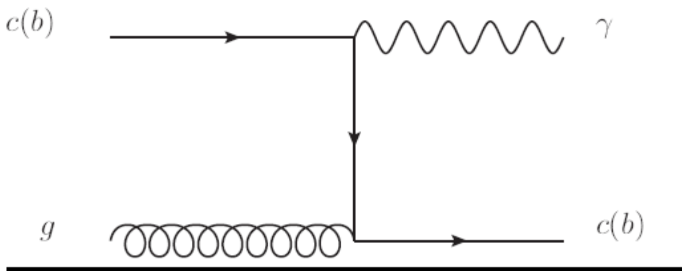
ABSTRACT

Constraints on the intrinsic charm probability $w_{c\bar{c}} = P_{c\bar{c}/p}$ in the proton are obtained for the first time from LHC measurements. The ATLAS Collaboration data for the production of prompt photons, accompanied by a charm-quark jet in pp collisions at $\sqrt{s} = 8$ TeV, are used. The upper limit $w_{c\bar{c}} < 1.93$ % is obtained at the 68 % confidence level. This constraint is primarily determined from the theoretical scale and systematical experimental uncertainties. Suggestions for reducing these uncertainties are discussed. The implications of intrinsic heavy quarks in the proton for future studies at the LHC are also discussed.

ArXiv: 1712.09096 [hep-ph], August 2018, EPJ C (in press)

V.A.Bednyakov, M.A. Demichev, G.L.,T.Stavreva, M.Stockton, Phys.Lett. B728, 602 (2014)
A.V.Lipatov, G.L., Yu.Yu.Stepanenko, V.A.Bednyakov, Phys.Rev. D94, 053011 (2016);
S.J.Brodsky, V.A.Bednyakov, G.L., J.Smiesko, S.Tokar, Prog.Part.Nucl.Phys. 93, 108 (2017).

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



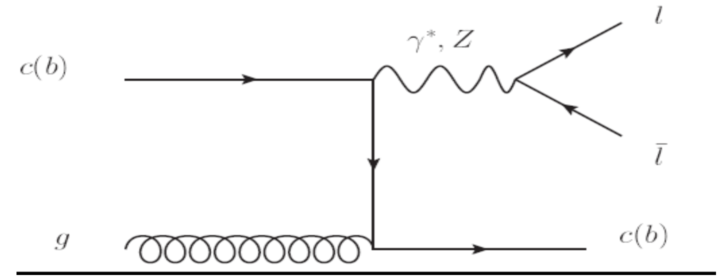


Fig.a. Feynman diagram for the process $c(b)+g\to\gamma+c(b)$

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

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

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

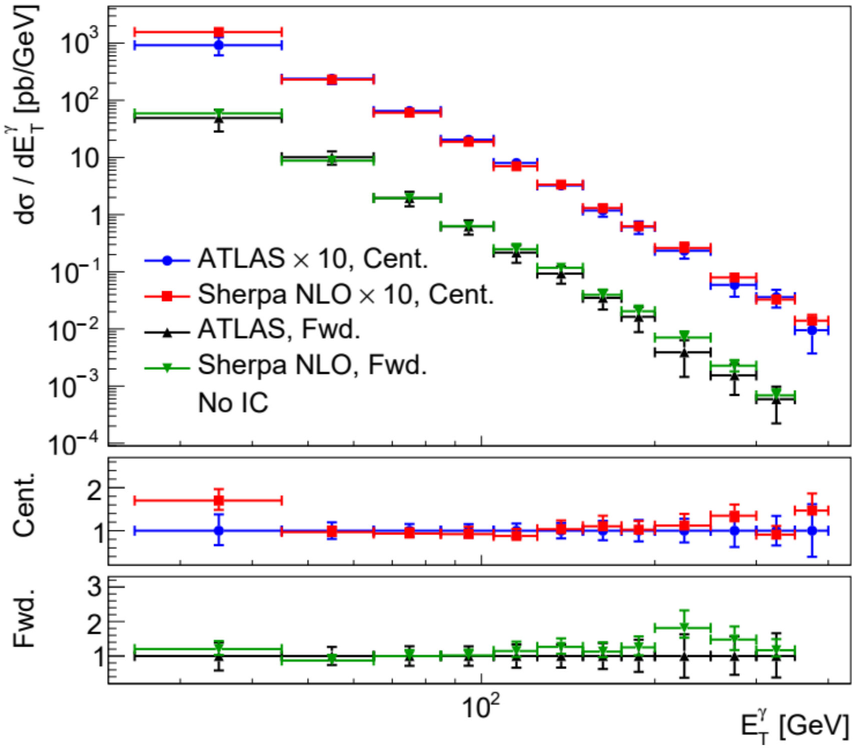
To observe the IC for Fig.a and Fig.b

$$x_c\geq x_F>0.1$$

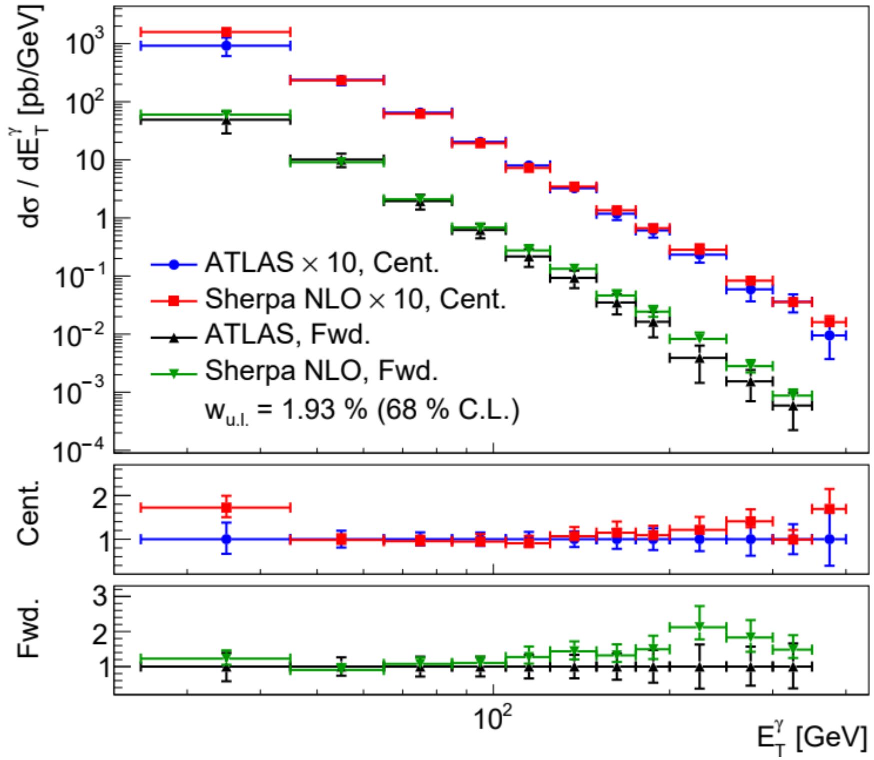
In our calculations we use the MC SHERPA (NLO) and combined QCD:
A.V.Lipatov, G.L.,M.A.Malyshev, A.A.Prokhorov, S.M.Turchikhin, Phys.Rev. D97, 114019 (2018) .

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

and conventional collinear QCD for quarks and antiquarks graphs



(a) $w_c = 0$ %



(b) $w_{u.l.} = 1.93$ %

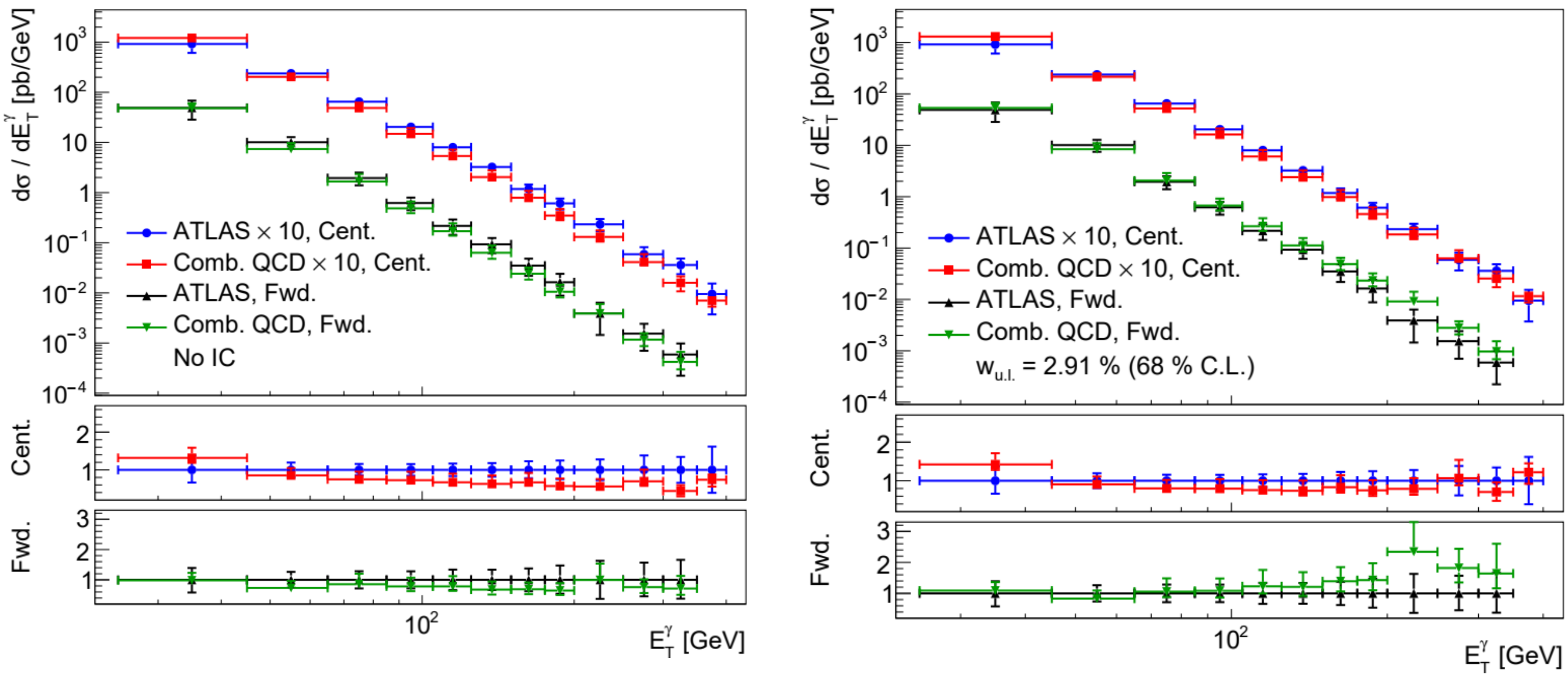
The transverse energy spectrum of photons calculated within SHRPA (NLO) compared with ATLAS data.

(a) top: the spectrum at central rapidity region $|\eta^{\gamma}| < 1.37$ and forward $1.56 < |\eta^{\gamma}| < 2.37$ region without the IC contribution;

(a) middle: the ratio of the MC calculation to the data for the central rapidity region ($w_c = 0\%$);

(a) bottom: the ratio of the MC calculation to the data for the forward rapidity region ($w_c = 0\%$)

(b): the same spectra, as in (a), but with the upper limit of IC contribution $w_{u.l.} = 1.93$ %.



(a) $w_c = 0$ %

(b) $w_{u.l.} = 2.91$ %

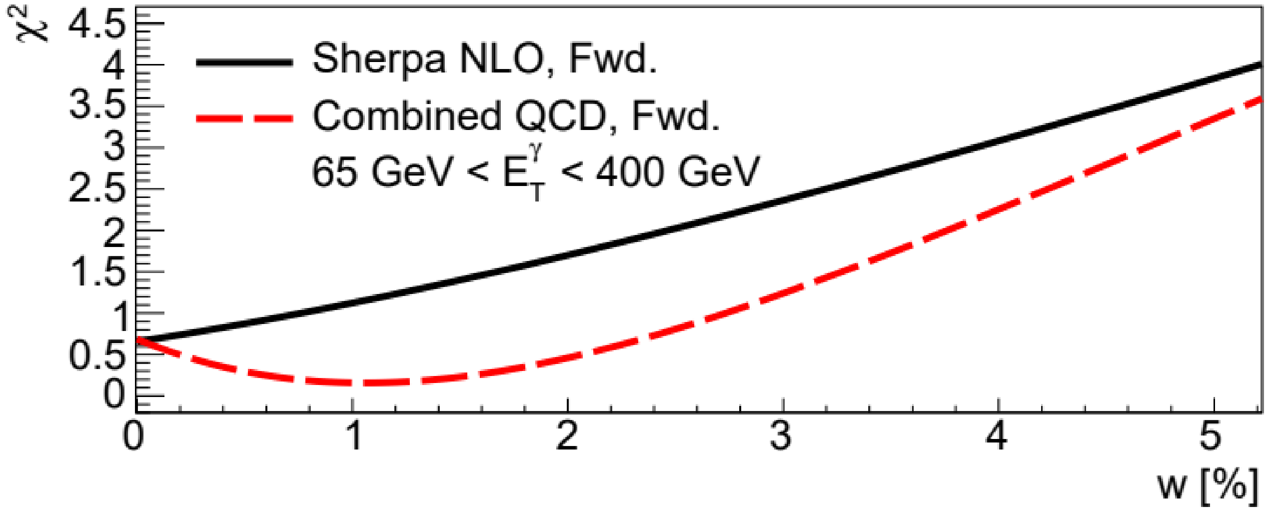
The transverse energy spectrum of photons calculated within combined QCD compared with ATLAS data.

(a) top: the spectrum at central rapidity region $|\eta^\gamma| < 1.37$ and forward $1.56 < |\eta^\gamma| < 2.37$ region without the IC contribution;

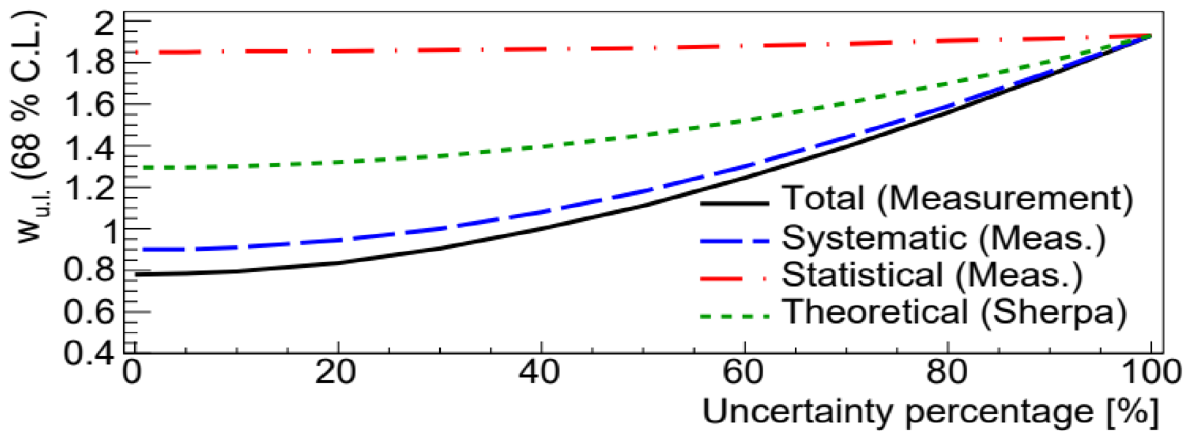
(a) middle: the ratio of the MC calculation to the data for the central rapidity region ($w_c = 0\%$);

(a) bottom: the ratio of the MC calculation to the data for the forward rapidity region ($w_c = 0\%$)

(b): the same spectra, as in (a), but with the upper limit of IC contribution $w_{u.l.} = 2.91$ %.



Solid line: $\chi 2$ as a function of w at the forward rapidity region in SHERPA NLO. is the same as the solid line but $\chi 2$ obtained within the combined QCD calculation.



The dependence of the IC upper limit $w_{u.l.}$ at 68% C.L. on the uncertainty percentage of the particular uncertainty component.

SUMMARY

1. A first estimate of the intrinsic charm (IC) probability w in the proton has been carried out from the recent ATLAS data.
3. Big experimental_and theoretical uncertainties allowed us to estimate only the upper limit of IC w_{ul} = 1.94% at CL=68 %.
4. To obtain more accurate results on the IC contribution one needs additional data and at the same time reduced systematic uncertainty coming from b-jet tagging.
5. One needs also the reduce of the theoretical uncertainties related to the QCD scale.
6. We show how our results on the upper limit of IC probability can be improved if these uncertainties are reduced.

THANK YOU VERY MUCH FOR YOUR ATTENTION !

We tahnk also A.A. Glazov, E.V. Khramov, S.M. Turchichin, I.R Boyko and A.N.Rusakovich for very helpful discussions

BACK UP

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.

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

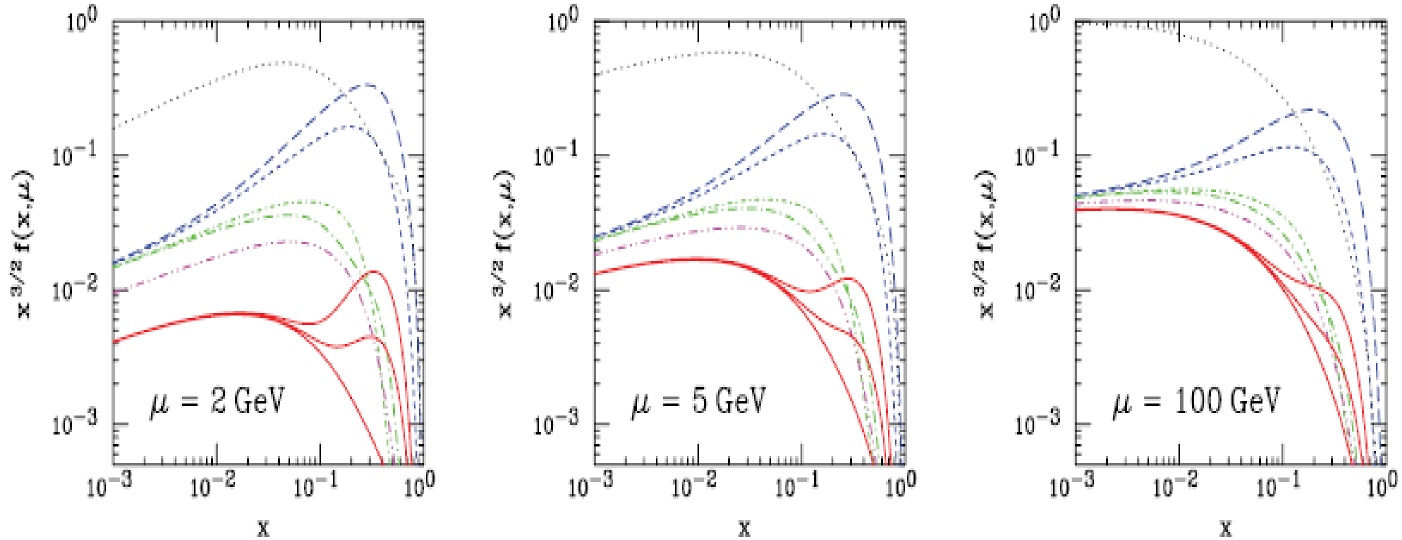
INTRINSIC HEAVY QUARK DISTRIBUTION IN PROTON

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

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

Where $\bar{N}_5=N_5/m_{4,5}^4$ normalization constant . Here $m_4=m_5=m_c$ m_c is the bar mass of the charmed quark. w_{IQ} determines some probability to find the Fock state $|uudQ\bar{Q}$ in the proton at $x_5\to 1$

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

PRODUCTION OF HEAVY FLAVOURS IN HARD P-P COLLISIONS

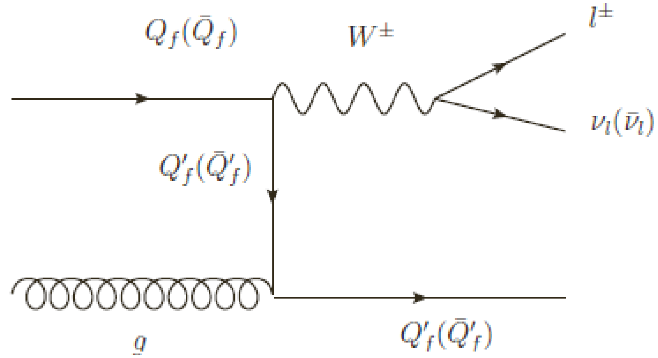
$$E\frac{d\sigma}{d^3p} = \sum_{i,j}\int d^2k_{iT}\int d^2k_{jT}\int_{x_i^{\min}}^1 dx_i\int_{x_j^{\min}}^1 dx_j f_i(x_i,k_{iT})f_j(x_j,k_{jT})\frac{d\sigma_{ij}(\hat{s},\hat{t})}{d\hat{t}}\frac{D_{i,j}^h(z_h)}{\pi z_h}$$

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

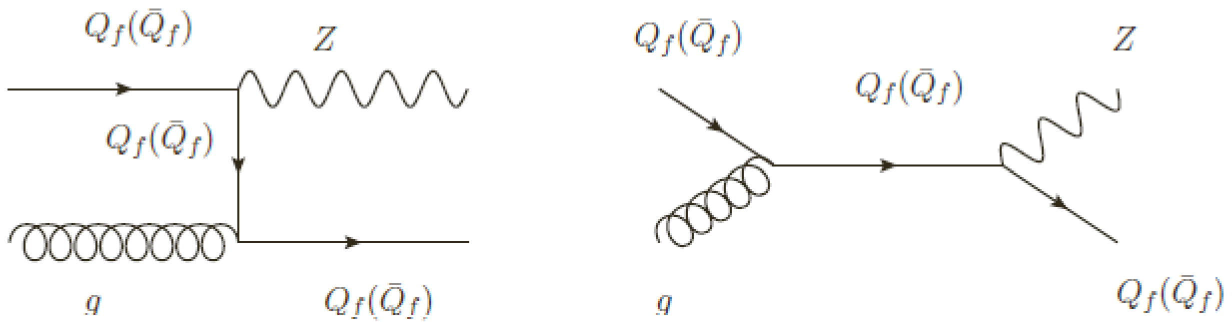
$$x_i^{min} = \frac{x_R+x_F}{2-(x_R-x_F)} \qquad x_R = 2p/\sqrt{s}$$

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_T 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.

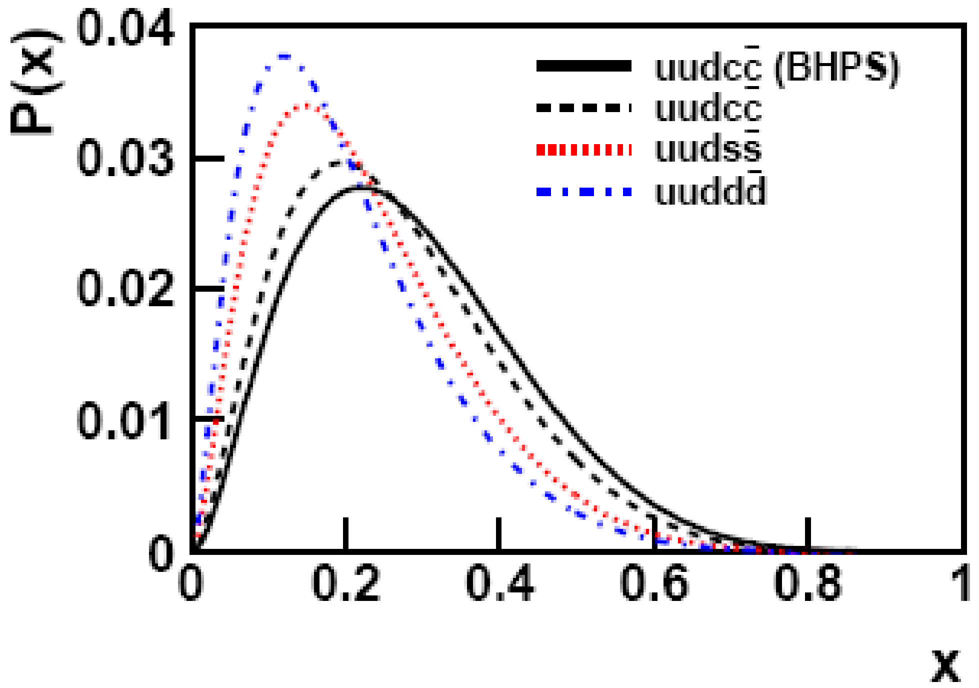
pp →W/Z+heavy flavour jets



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 $Q_f(\bar{Q}_f)g \to ZQ_f(\bar{Q}_f)$



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.