HEAVY FLAVOUR QUARK DISTRIBUTIONS: COLLIDER TESTS

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in collaboration with
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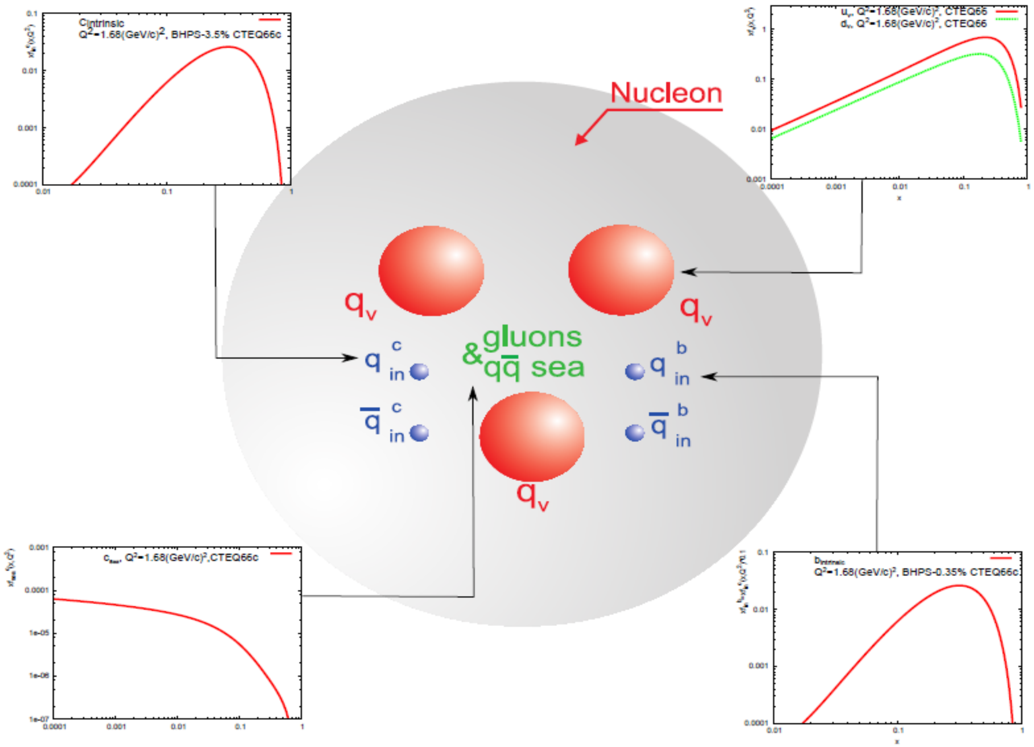
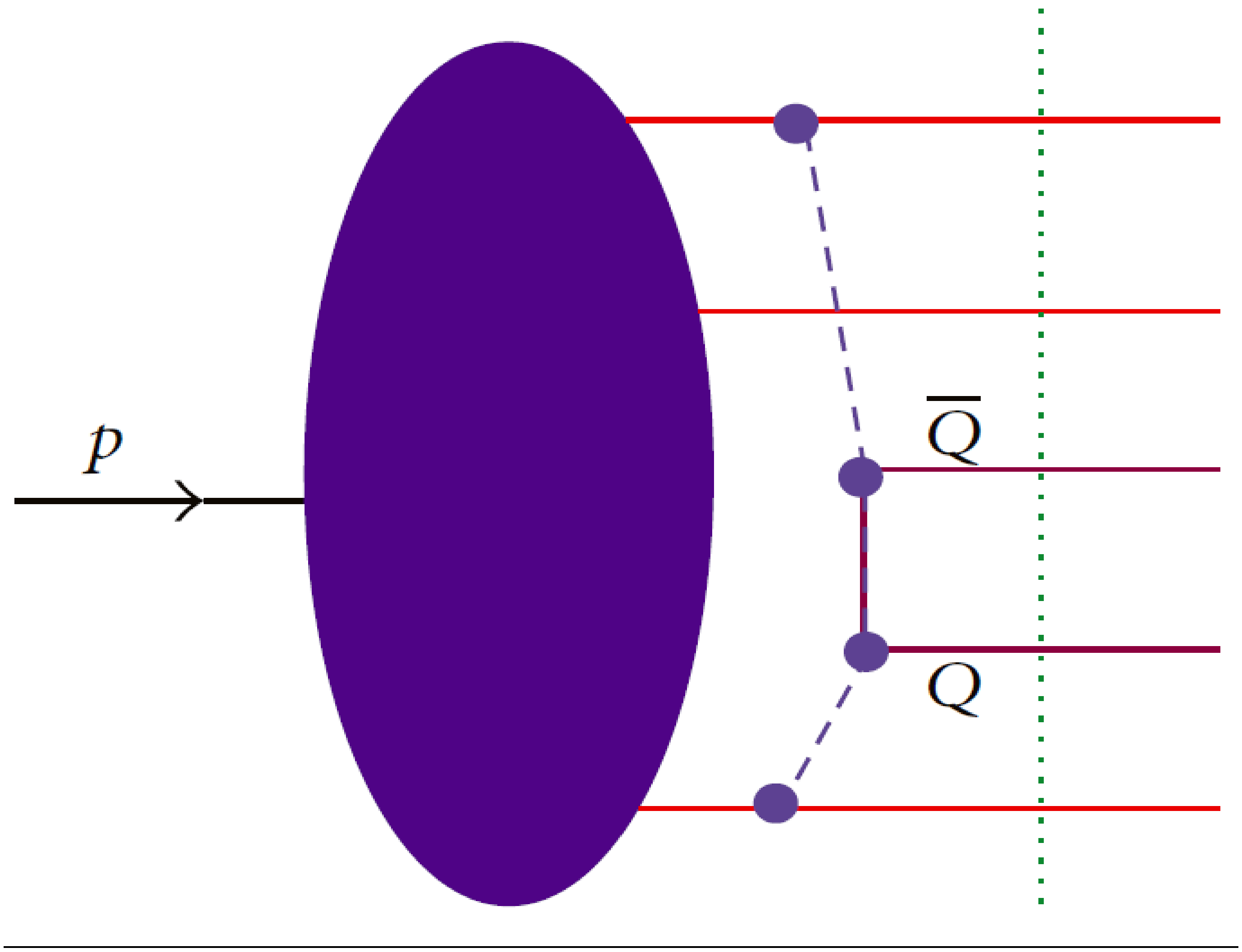
OUTLINE

1. Intrinsic heavy flavours in proton
2. Main goal of our study
3. Search for intrinsic charm *(IC)* from γ+c(b) and W/Z+c(b) production in p-p collision
4. Observables very sensitive to the *IC* contribution
5. Summary

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**

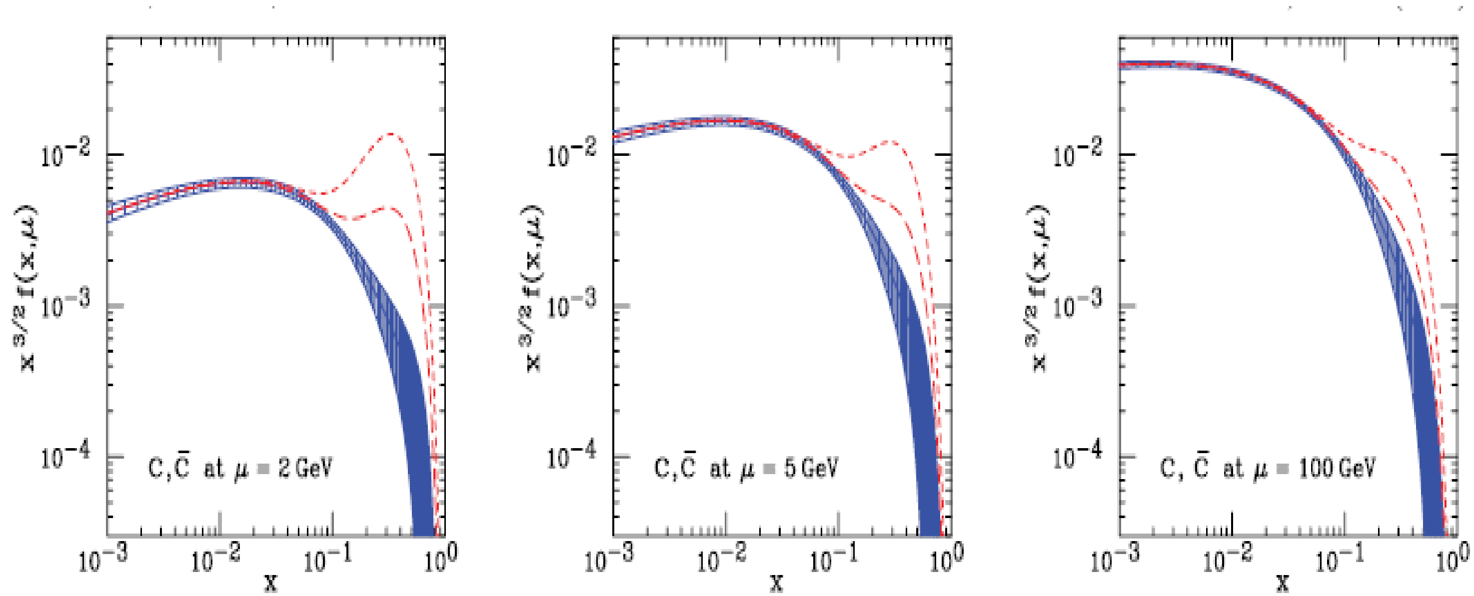
Intrinsic $Q\bar{Q}$ in proton





Cut gluon-gluon scattering box diagram gg->Q Qbar inserted into the proton self-energy

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

Main goal: searching for the signal of the intrinsic charm (IC) contribution in proton from the analysis of the prompt photon or Z/W boson production in p-p collision accompanied by heavy c(b)-jet.

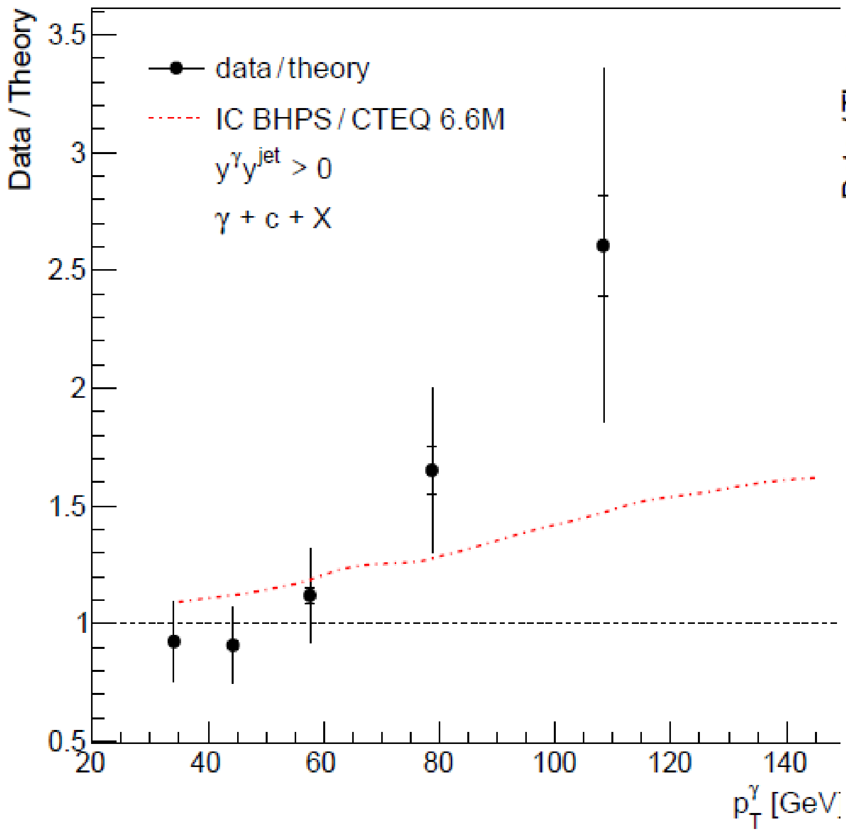
STATUS OF SEARCHING FOR INTRINSIC CHARM AT ATLAS EXPERIMENTS

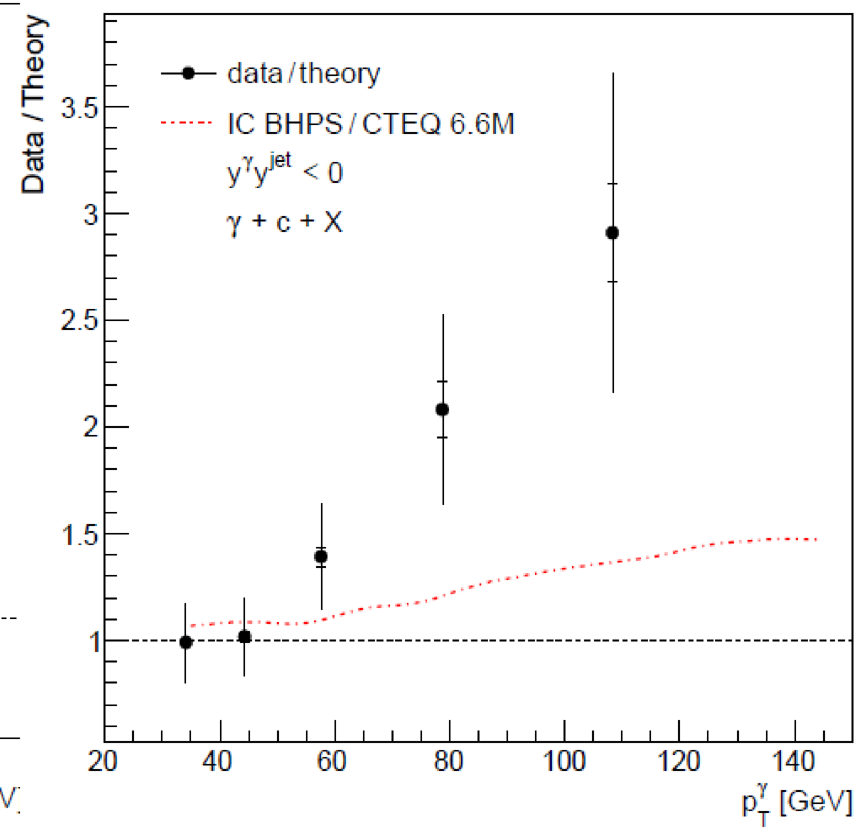
We have already predictions on

PP->γ + c +X *V.A.Bednyakov, M.A.Demichev,G.L.,T.Stavreva, M.Stockton, Phys.Lett. B728, 602 (1914)*

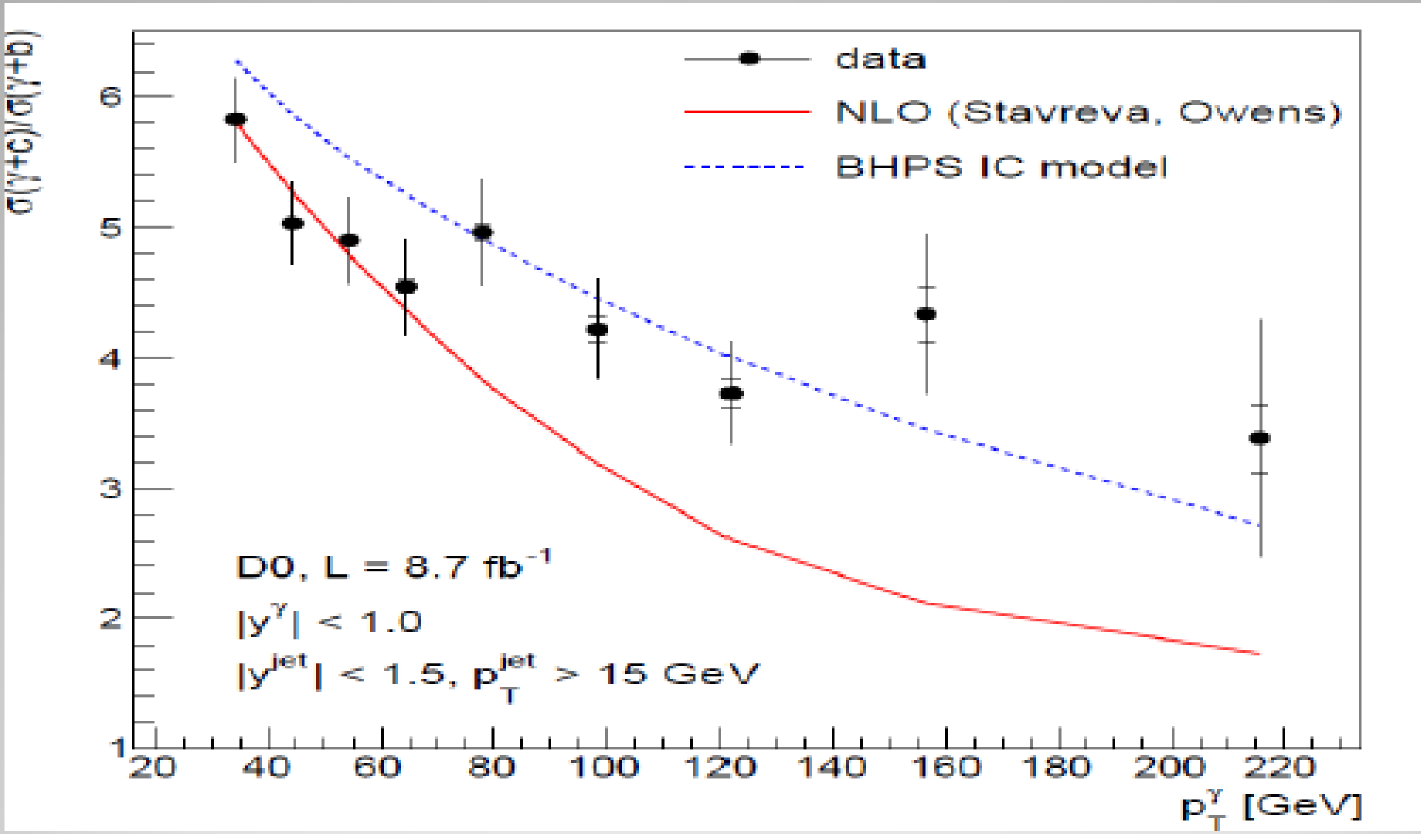
and ***PP->Z/W+ c(b)+X*** *H.Beauchemin, V.A.Bednyakov,G.L., Yu. Yu. Stepanenko, Phys.Rev.D92, 034014 (2015)*

$p\bar{p} \rightarrow \gamma + c(b) + X$ **D0 experiment at Tevatron** $s^{1/2} = 1.96 TeV$



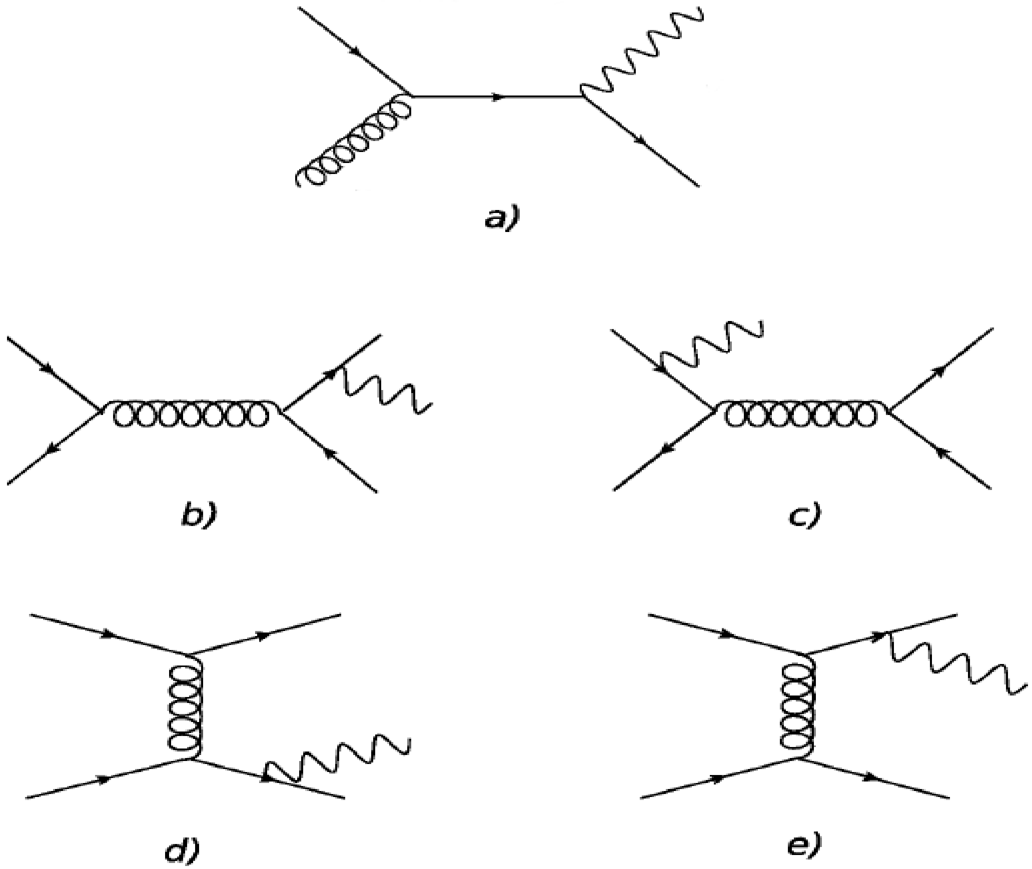


R=σ(γ + c)/σ(γ + b) for p bar{p} -> γ + Q at $s^{1/2}$ = 1.98 TeV



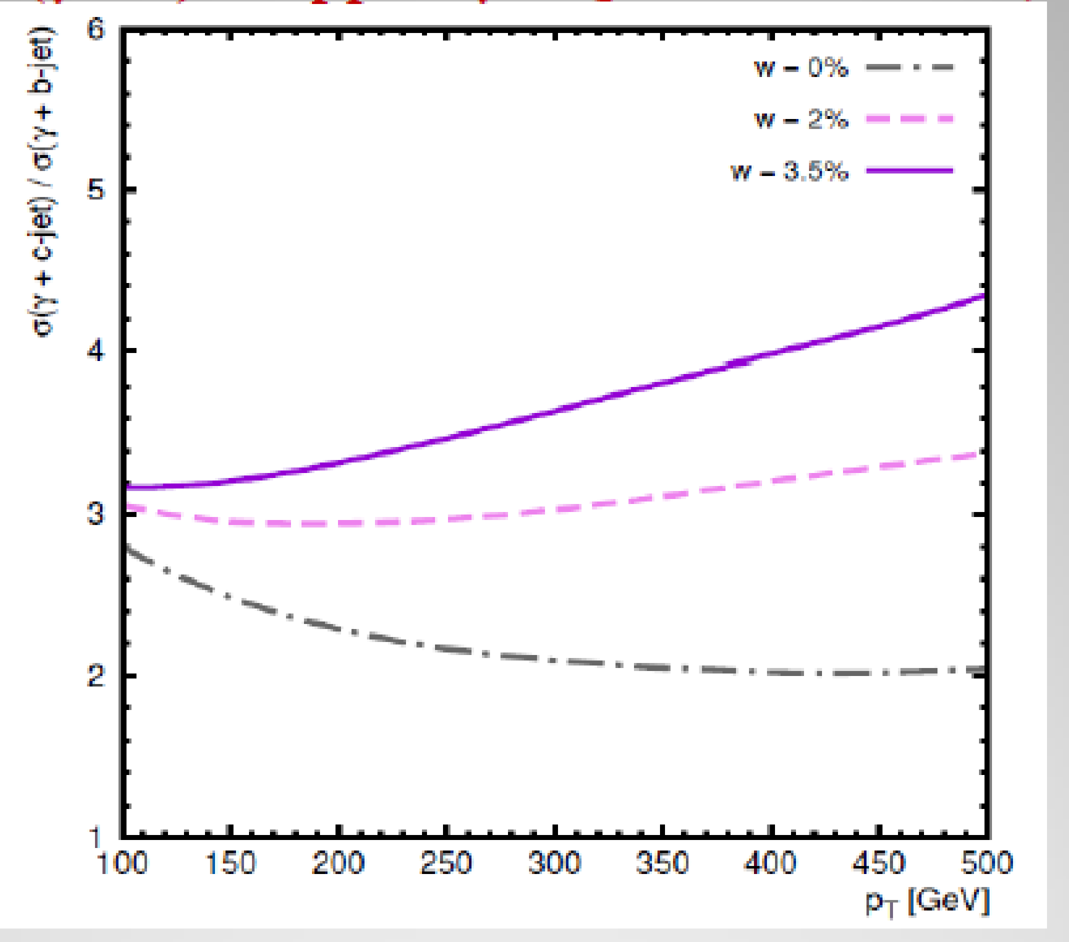
p_T –distribution of R, points are the D0 data; red solid line is NLO without *IC* ; short dash line is BHPS with *IC* probability about 1 %

$pp \rightarrow \gamma + Q + X, Q = c,b$



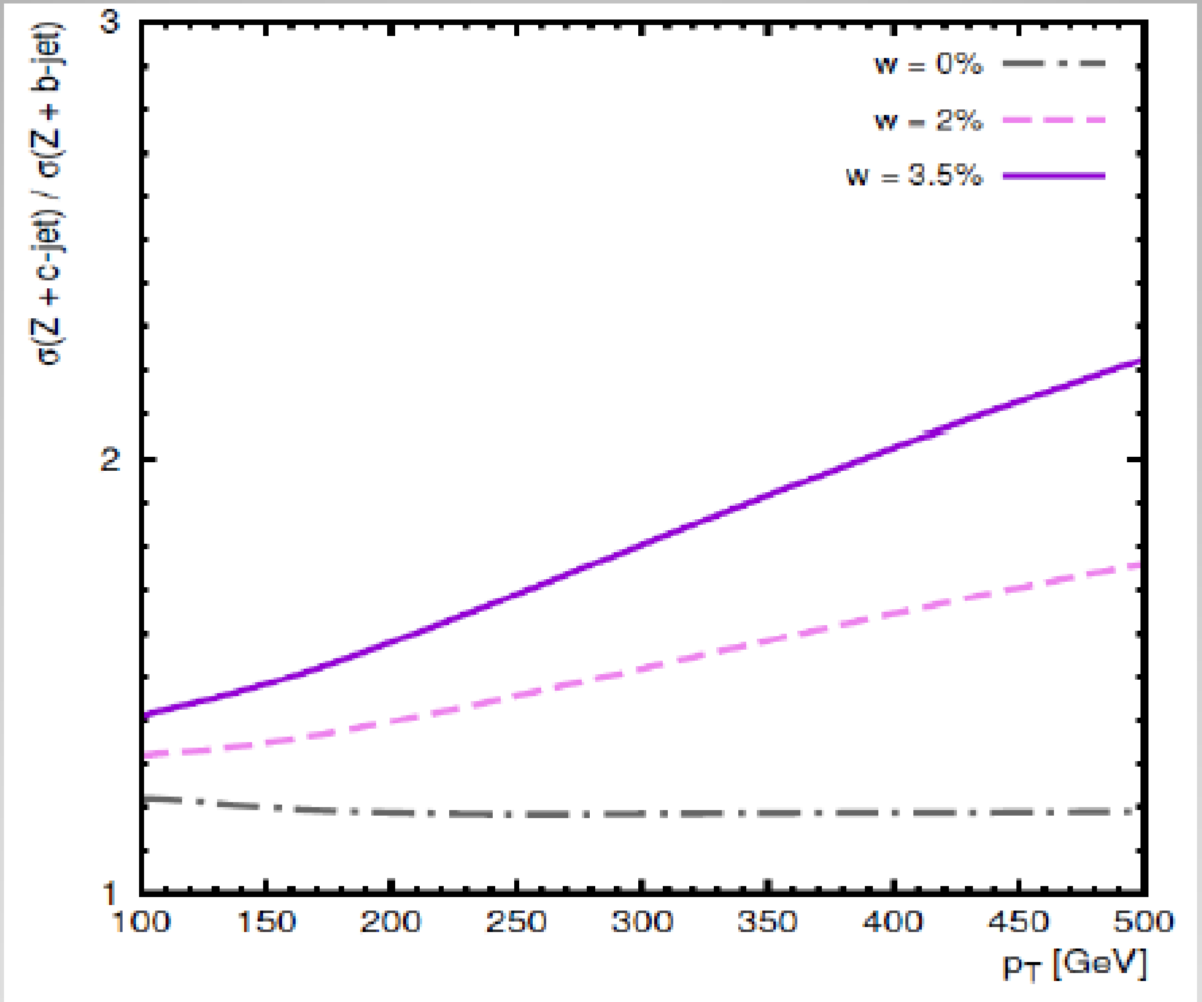
Feynman QCD diagrams: a): Q +g->γ +Q;
b-c): Q + barQ->Q + barQ + γ; d-e): Q(q)+q(Q)->Q(q)+q(Q)+γ

$R=\sigma(\gamma + c)/\sigma(\gamma + b)$ for $pp \to \gamma + Q$ at $s^{1/2} = 8$ TeV ; $1.5< \eta< 2.4$



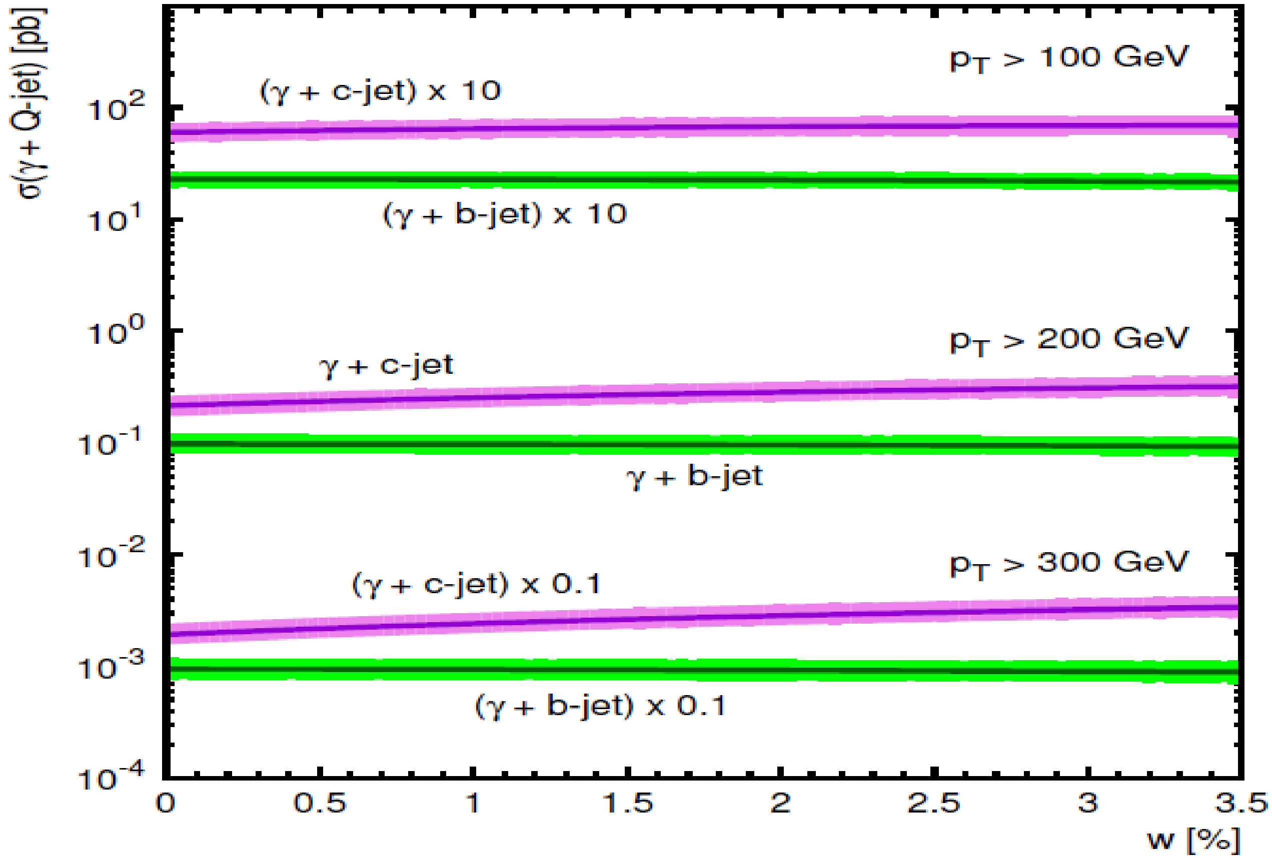
p_T –distribution of R at different IC probability w

R=σ(Z + c)/σ(Z + b) for pp -> Z+ Q at $s^{1/2}$ = 8 TeV ; 1.5< η< 2.4



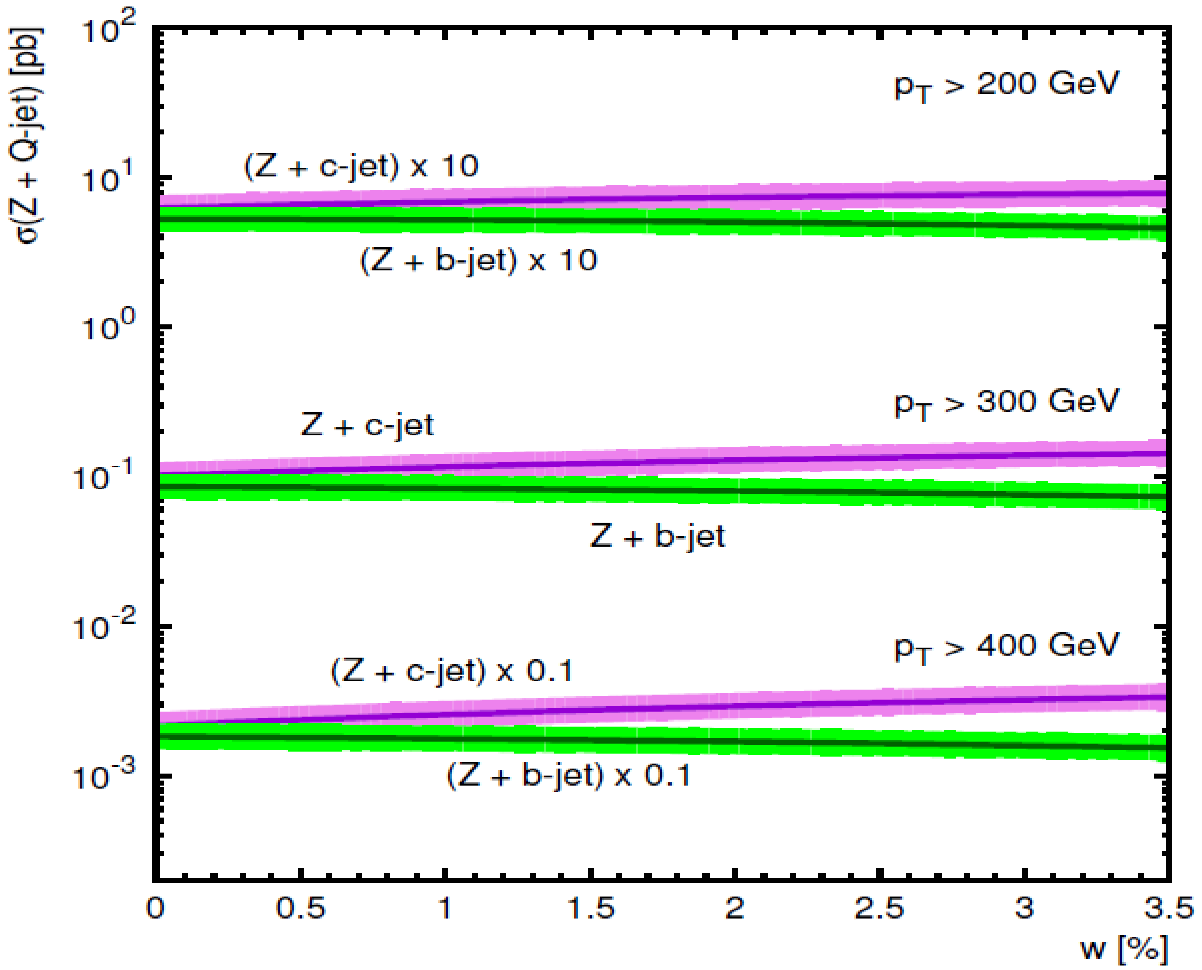
p_T –distribution of R at different IC probability w

$\sigma(\gamma + Q)$ at $s^{1/2} = 8$ TeV ; $1.5 < \eta < 2.4$; $Q = c,b$

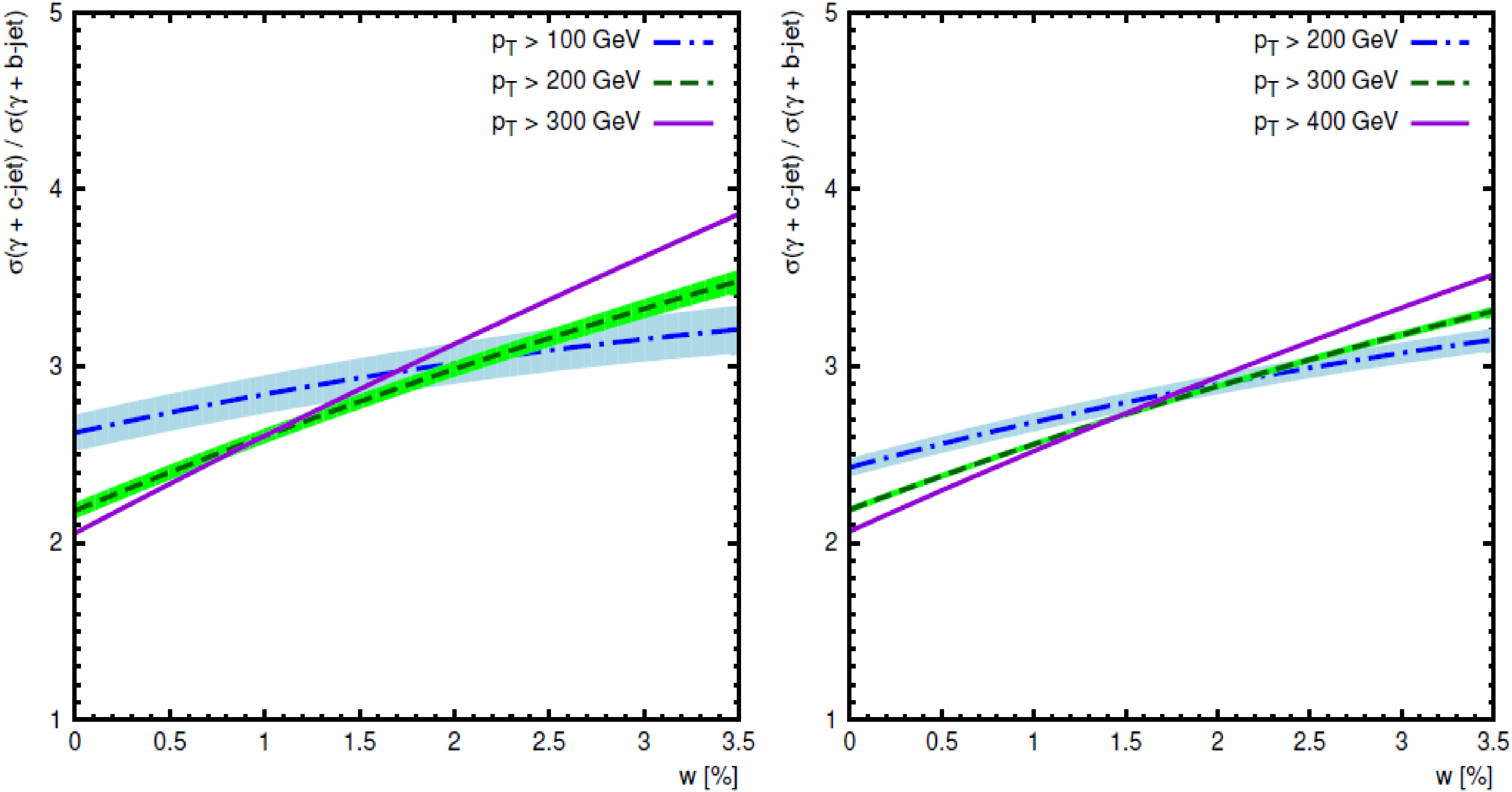


p_T^γ – spectrum integrated over p_T^γ , i.e., $\sigma(\gamma+c)$ and $\sigma(\gamma+b)$ at $p_T^\gamma > 100$ GeV or 200 GeV, or 300 GeV, vs. *IC* probability w

σ(Z + Q) at $s^{1/2}$ = 13 TeV ; 1.5< η< 2.4; Q = c,b

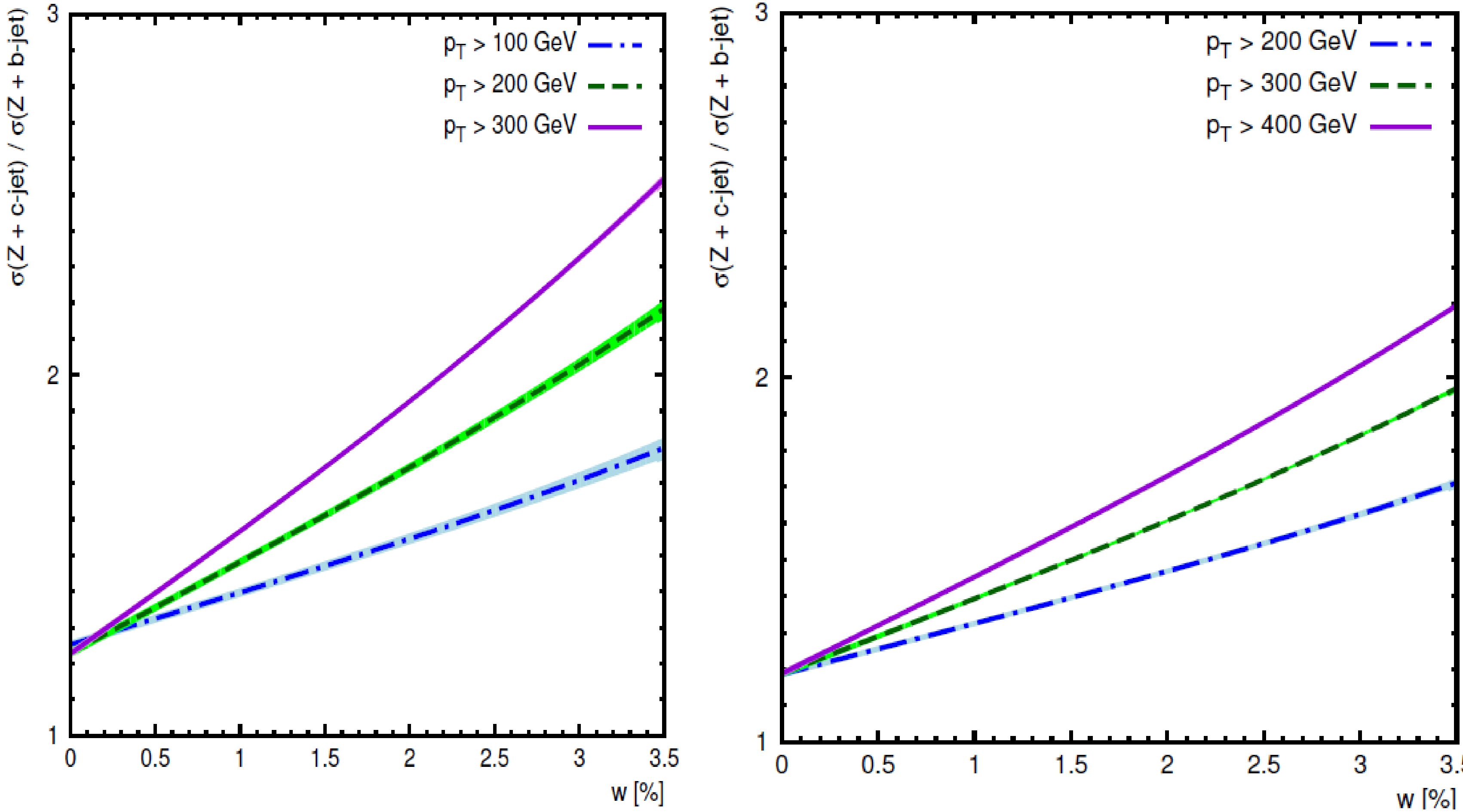


$s^{1/2} = 8$ TeV $\quad$ PP → γ + Q +X , Q = c,b $\quad$ $s^{1/2} = 13$ TeV



Ratio between the x-sections of γ +c and γ + b production integrated over p_T. Bands mean the QCD scale uncertainty

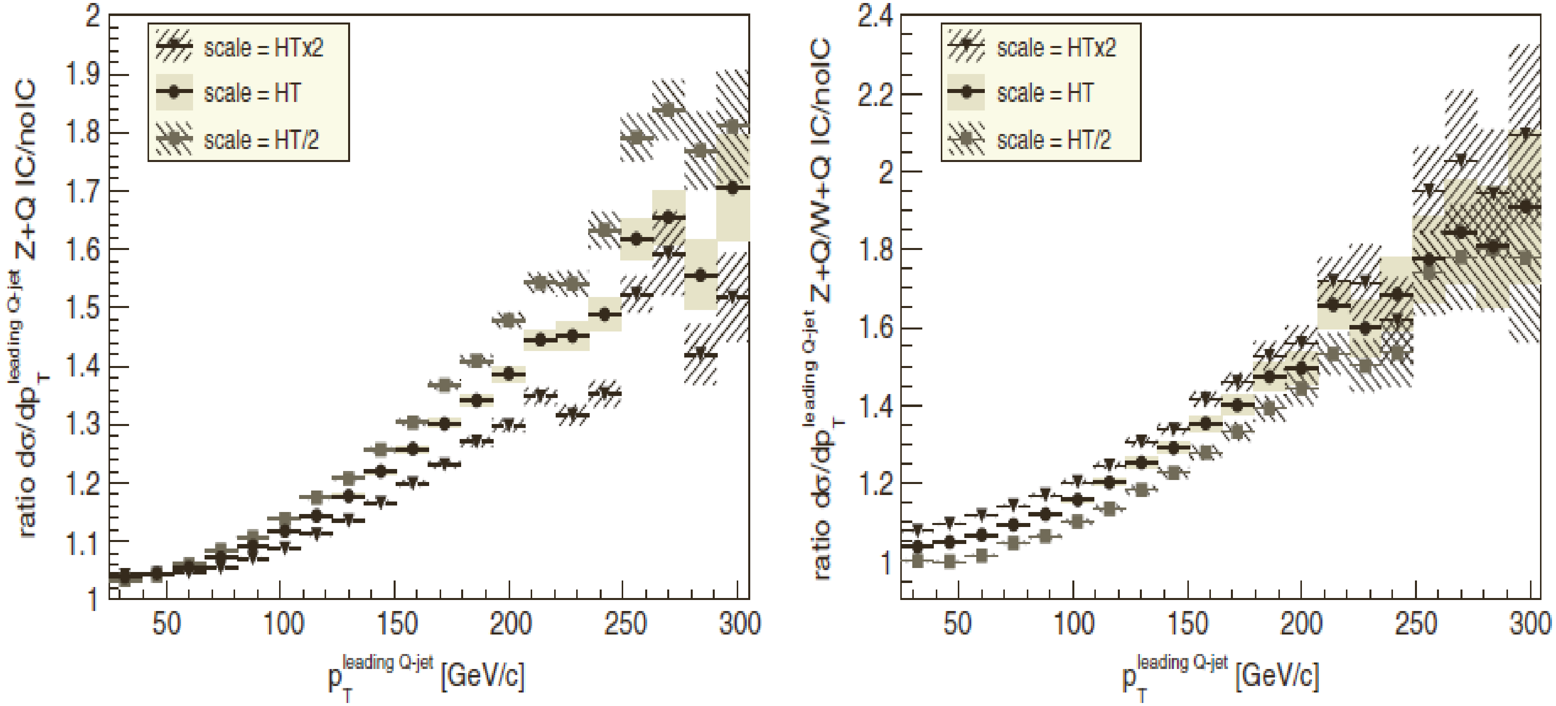
Ratio σ(Z+c)/σ(Z+b)
$S^{1/2}$ = 8 TeV (left) and $S^{1/2}$ = 13 TeV (right)



Ratio between the x-sections of γ +c and γ + b production integrated over p_T. Bands mean the QCD scale uncertainty

A.V.Lipatov, G.L., Yu.Yu.Stepanenko, V.A.Bednyakov, hep-ph/ 1606.04882v2; Phys.Rev. D94 , 053011 (2016)

Scale uncertainty for Z+Q and Z+Q/W+Q



Left: Z+Q with IC and without IC at different scales
Right: Z+Q/W+Q with IC and without IC at different scales

P.A.Beauchemin, V.A.Bednyakov, G.L., Yu.Yu.Stepanenko, Phys.Rev.D92, 034014 (2015)

SUMMARY

1. Ratio $R = \sigma(\gamma/Z+c)/\sigma(\gamma/Z+b)$ vs. p_T^γ is flat or increases if the *IC* is included in PDF, when p_T^γ grows. In absence of the *IC* contribution R decreases , when p_T^γ increases.
2. We predict the x-sections for $\gamma/Z+c$ and $\gamma/Z+b$ productions integrated over p_T^γ within the different p_T^γ –cuts.
3. The ratio of these x-sections is sensitive to the QCD scale uncertainty much smaller compered to the x-sections. This uncertainty is less than 1 % at $s^{1/2} = 13$ TeV and about 1%-2% at $s^{1/2} = 8$ TeV .
4. We recommend to measure the ratio $R = \sigma(\gamma/Z+c)/\sigma(\gamma/Z+b)$ at large p_T^γ - beans: 100-500 GeV, 200-500 GeV, 300-500GeV to observe a possible *IC* signal.

THANK YOU VERY MUCH FOR YOUR ATTENTION !

BACK UP

INTRINSIC HEAVY QUARK STATES

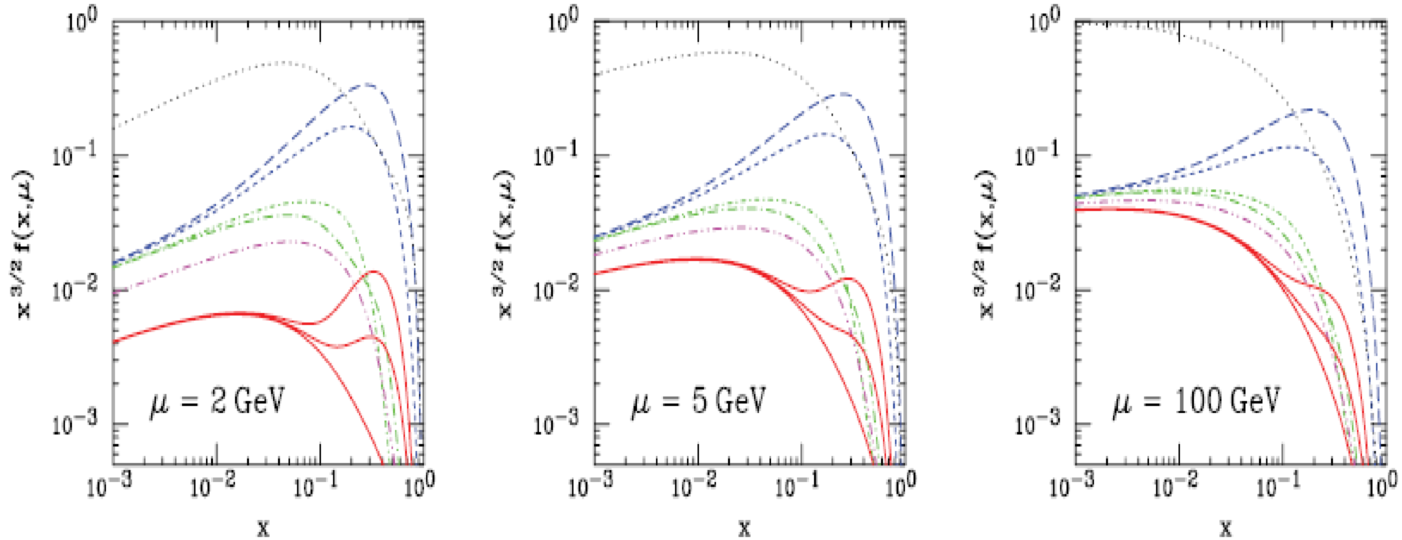
Two types of parton contributions

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.

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

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

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

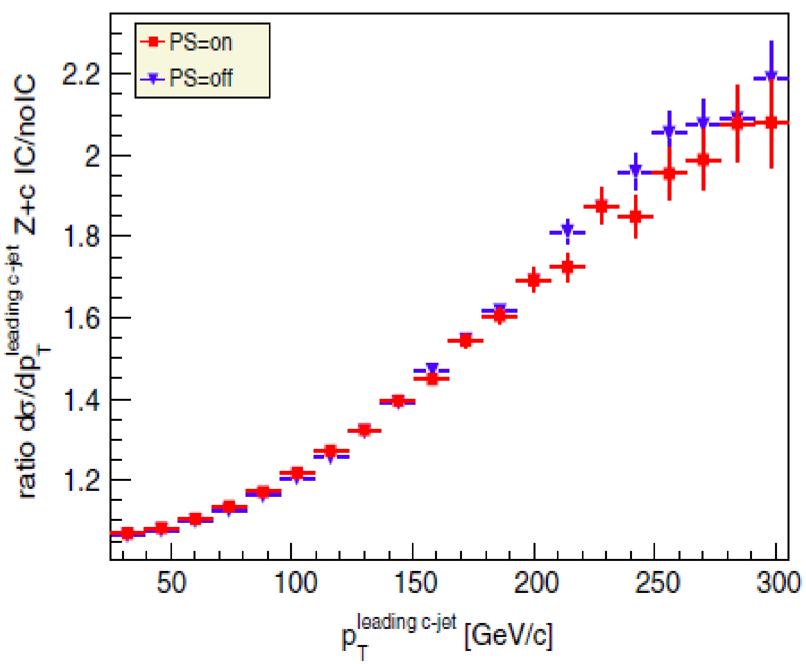
$$x_i^{\min} = \frac{x_T\cot(\frac{\theta}{2})}{2 - x_T\tan(\frac{\theta}{2})} \qquad x_F \equiv \frac{2p_z}{\sqrt{s}} = \frac{2p_T}{\sqrt{s}}\frac{1}{\tan\theta} = \frac{2p_T}{\sqrt{s}}\sinh(\eta)$$

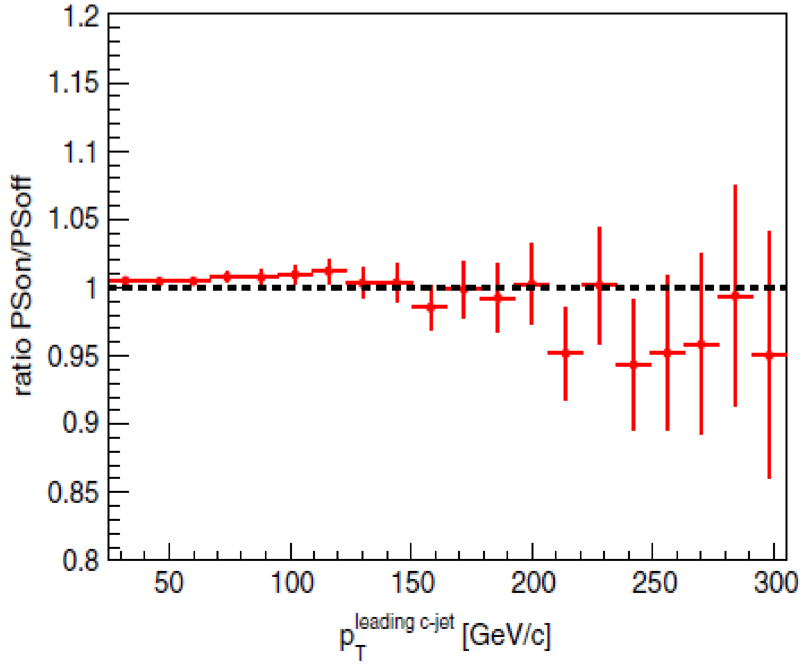
$$x_i^{min} = \frac{x_R + x_F}{2 - (x_R - x_F)} \qquad x_R = 2p/\sqrt{s}$$

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.

Inclusion of parton shower by Z+Q production in pp at $s^{1/2}$ =8 TeV

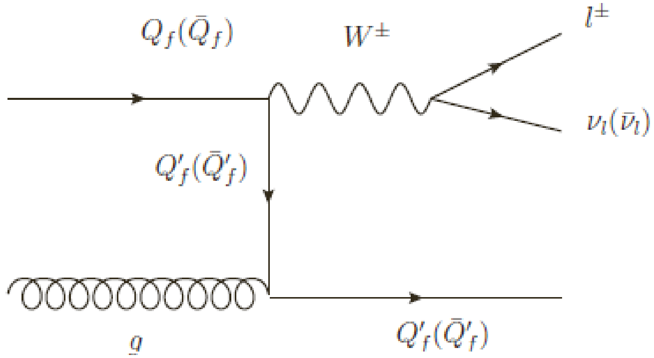




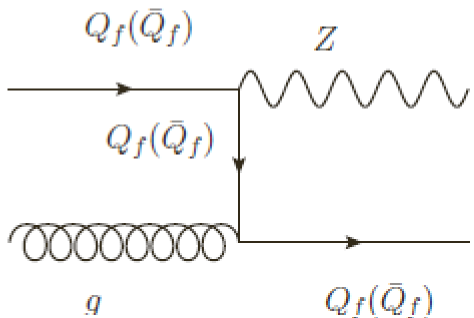
Left: p_T – spectra with parton shower (red points) and without it (blue points) using the PDF of type CTEQ66c (*3.5%* of *IC*)

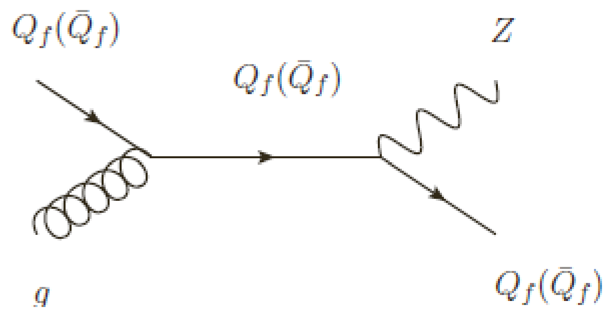
Right: ratio of red points to blue points

pp →W/Z+heavy flavour jets



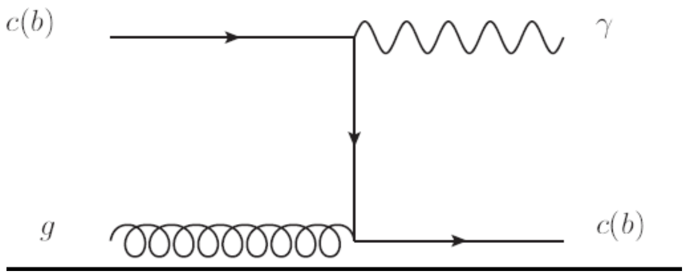
The LO Feynman diagrams for the process $Q_f(\bar{Q}_f)g \to W^{\pm}Q'_f(\bar{Q}'_f)$, where $Q_f = c.b$ and $Q'_f = b, c$ respectively.





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

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



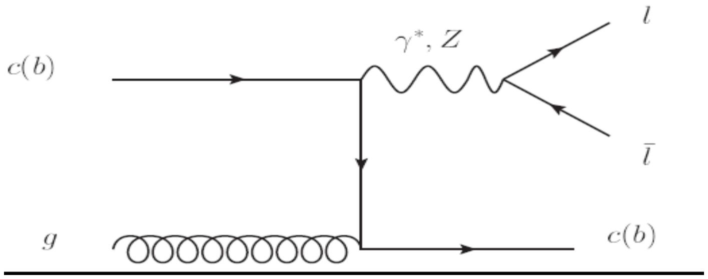


Fig.a. Feynman diagram for the process $c(b)+g\to\gamma+c(b)$

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

$$x_c\geq x_F>0.1$$

for Fig.b

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

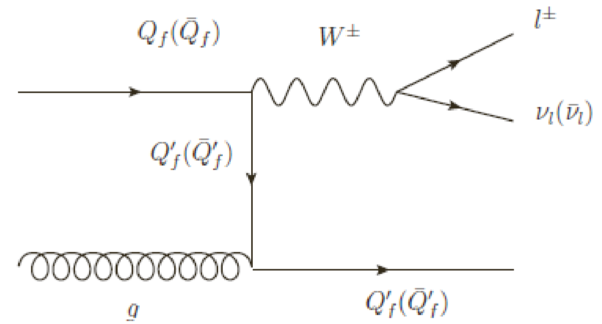


Figure 2: The LO Feynman diagrams for the process $Q_f(\bar{Q}_f)g \to W^{\pm}Q'_f(\bar{Q}'_f)$, where $Q_f = c.b$ and $Q'_f = b, c$ respectively.

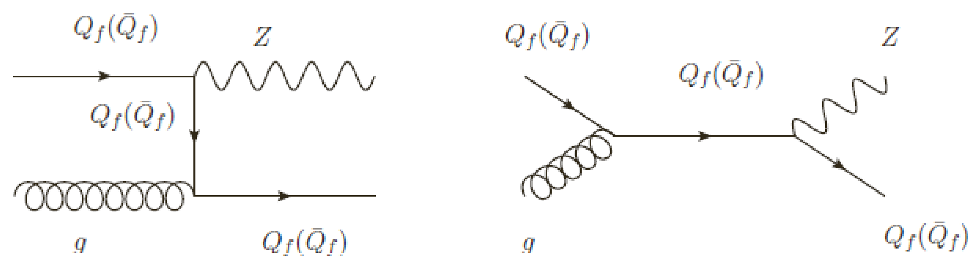
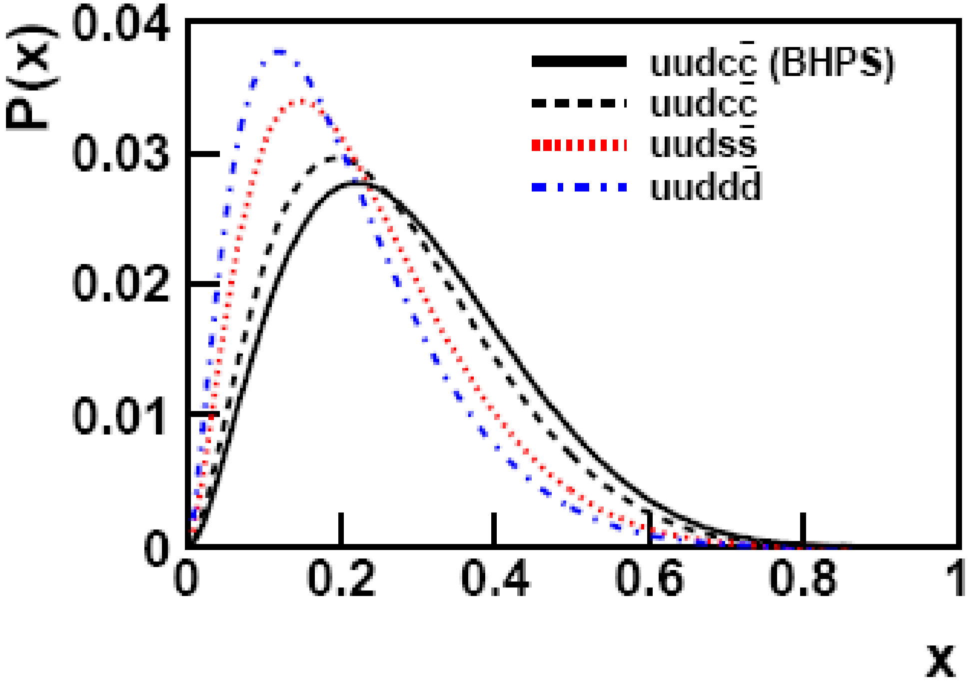


Figure 3: Feynman diagram for the process $Q_f(\bar{Q}_f)g \to ZQ_f(\bar{Q}_f)$



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.