SEARCH for INTRINSIC CHARM in Z/γ+c PRODUCTION in p-p at ATLAS

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in collaboration with

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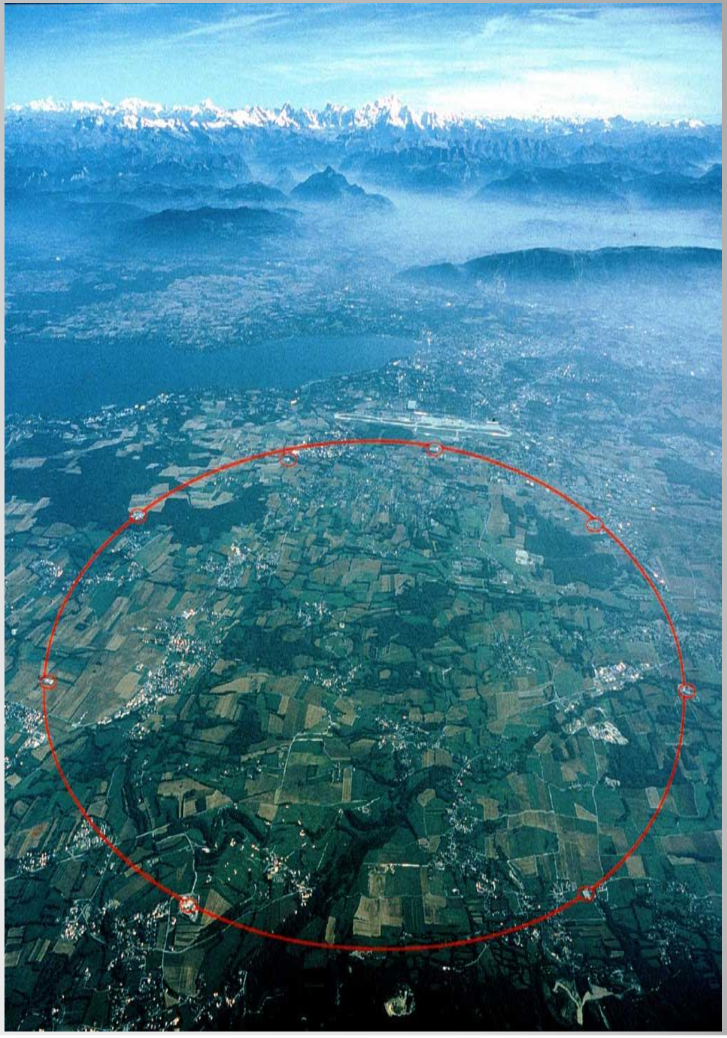


OUTLINE

1. Motivation of this study.

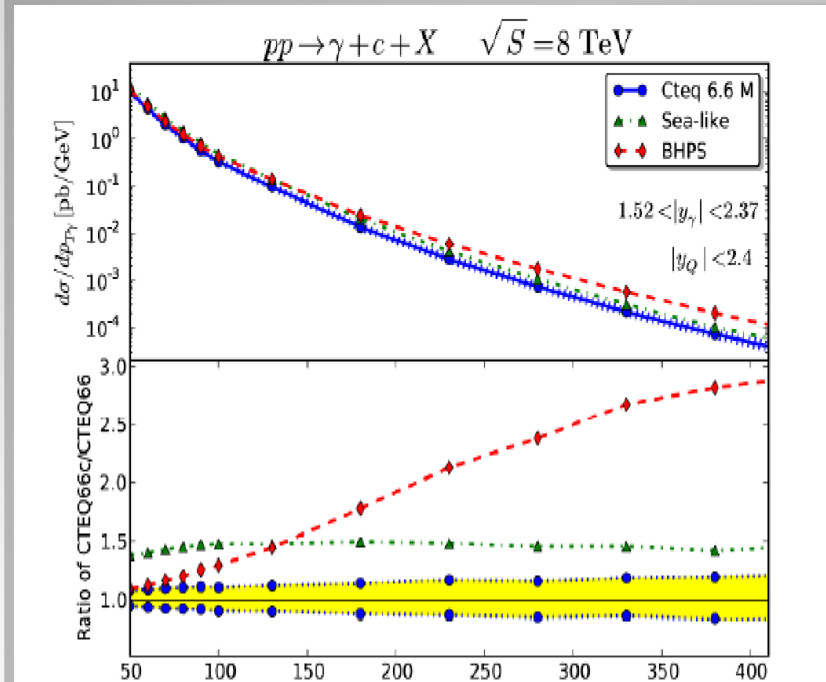
2. Intrinsic charm (*IC*) and ratio $\sigma_{pp}(\gamma+c)/\sigma_{pp}(\gamma+b)$ as a function of p_T.

3. Ratio $\sigma_{pp}(Z+c)/\sigma_{pp}(Z+b)$ as a function of the *IC probability.*

4. Ratio $\sigma_{pp}(Z+c)/\sigma_{pp}(Z+b)$ as a function of p_T and the highest possible *IC* signal .

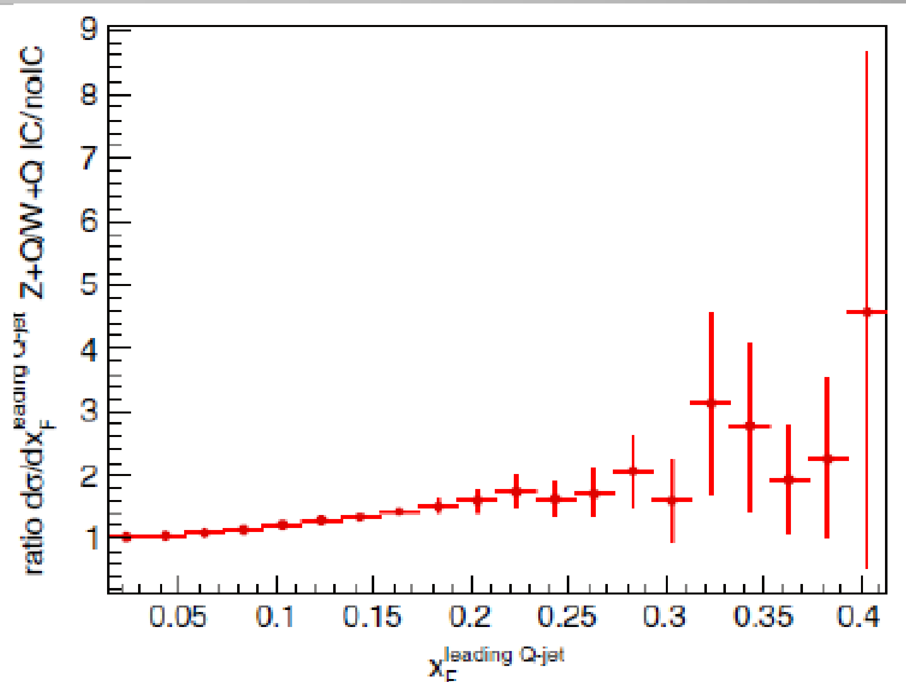
5. Summary.

PP -> γ + c + X, $s^{1/2}$ = 8 TeV *PP -> Z/W + Q +X , $s^{1/2}$ = 8 TeV*



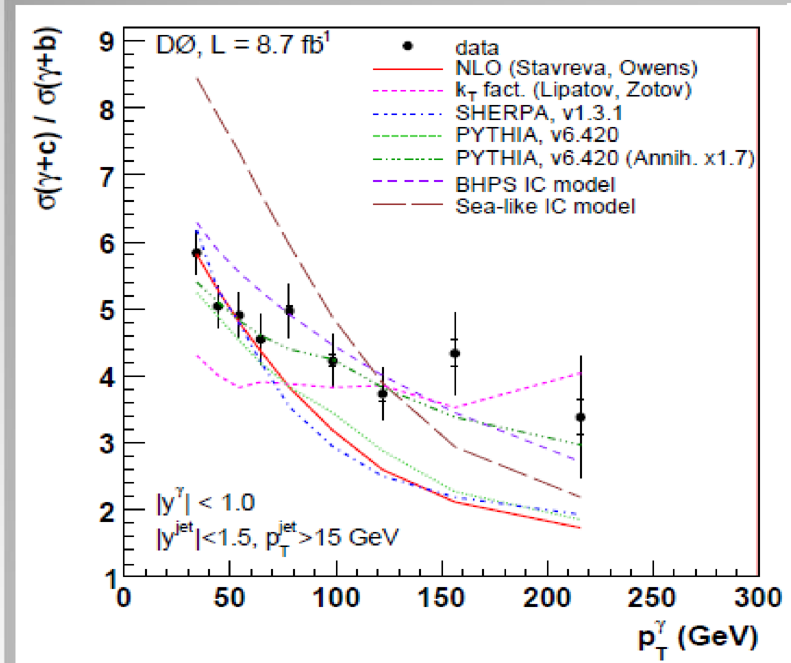
pT (GeV/c)

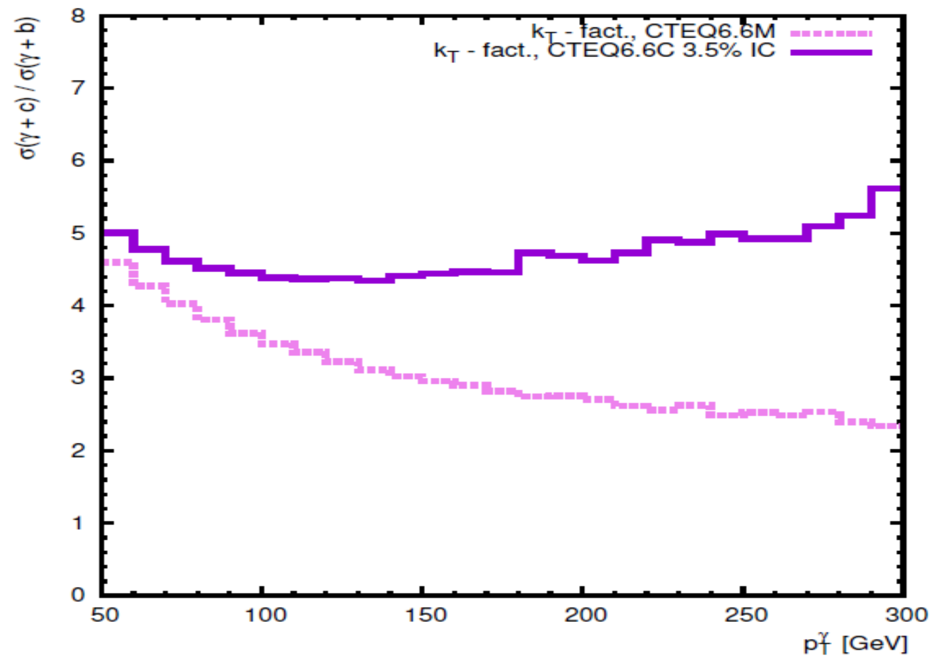
V.A.Bednyakov, M.A.Demichev, G.L., T.Stavreva, M.Stockton, Phys.Lett. B728, 602(2014).



P-H Beauchemin, V.A.Bednyakov, G.L., Yu.Yu. Stepanenko, Phys.Rev. D92 034014 (2015). Q = c or b .

New results on γ + c production in p-p





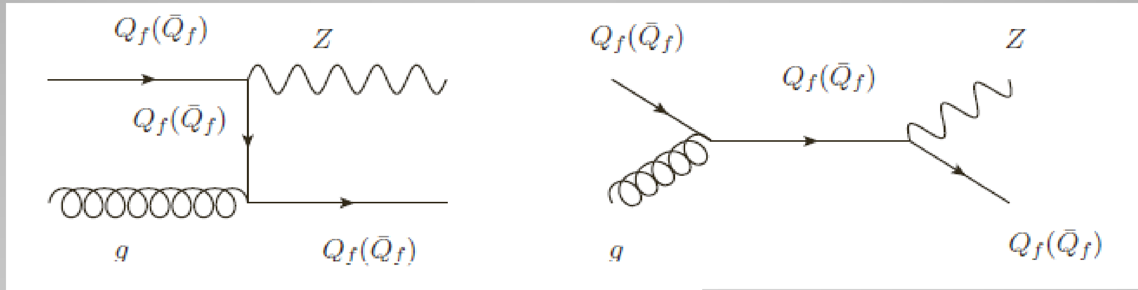
Ratio of differential cross sections of γ +c and γ +b productions as function of photon trancsverse momentum

Left : ***D0 data from TEVATRON and theoretical calculations***

D0 Collaboration, Phys. Lett. B **719**, 354 (2013); arXiv:1210.5033 [hep-ex].

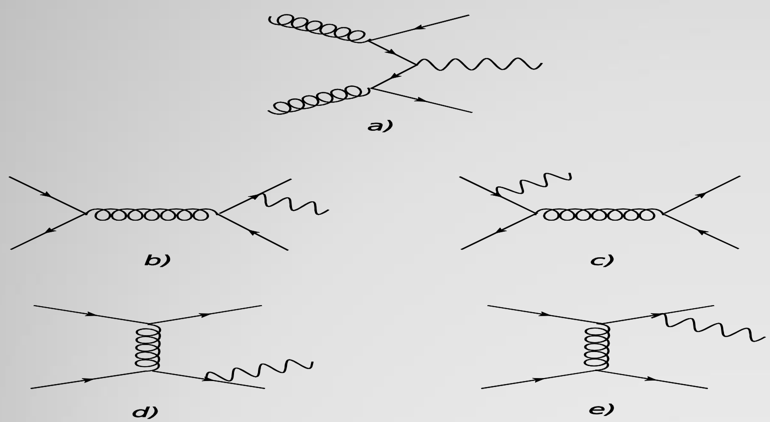
Right: ***our latest predictions with the IC (top line) and without it (bottom line)***

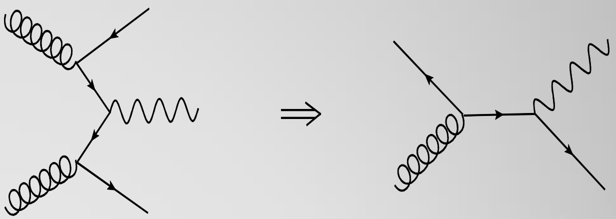
pp →Z + heavy flavour jets



$Q_f = c.b$ and $Q'_f = b, c$ respectively.

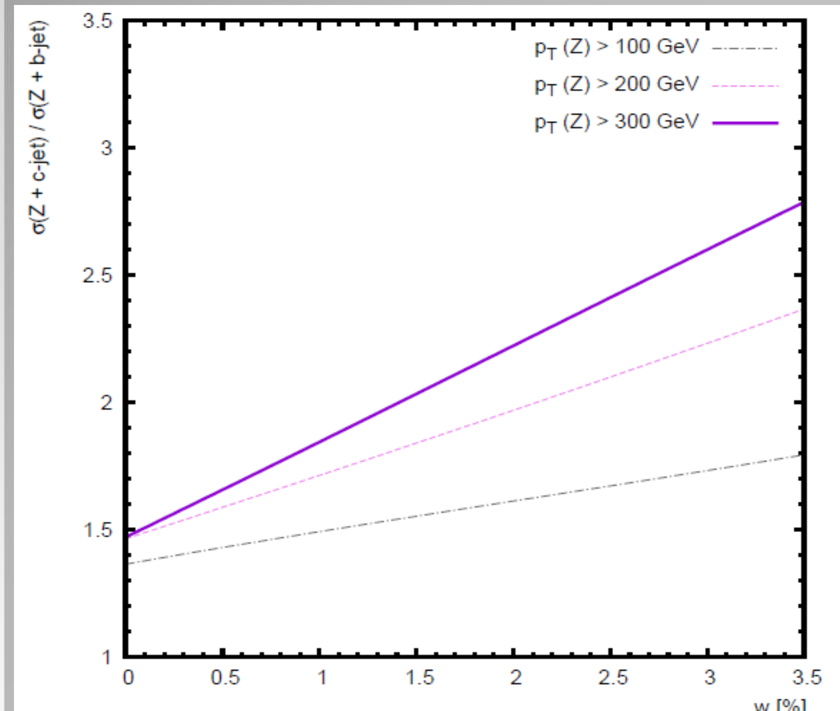
Feynman diagram for the process $Q_f(\bar{Q}_f)g \to ZQ_f(\bar{Q}_f)$

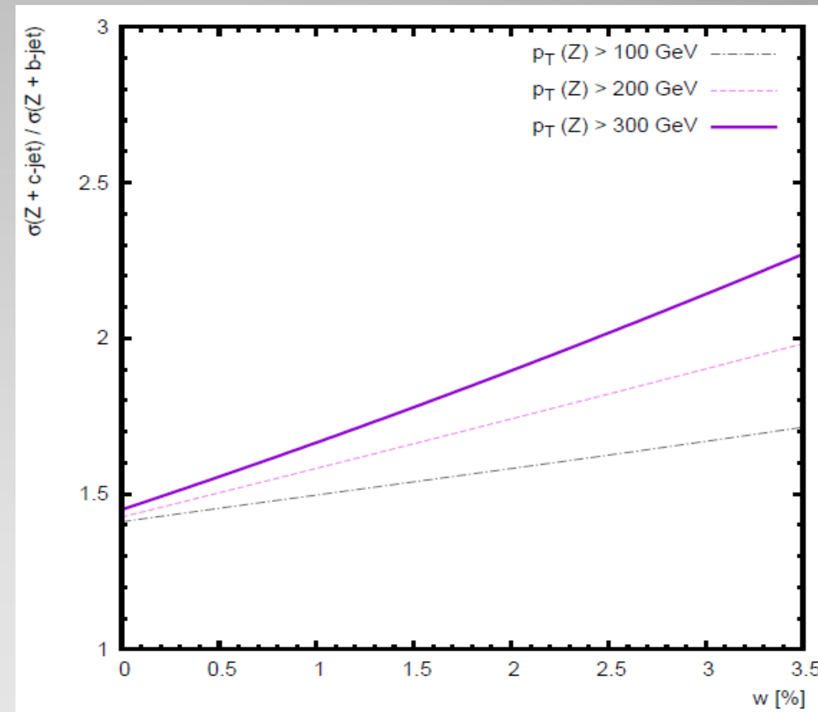




Feynman diagrams, which contribute to the Z+Q production in p-p collision

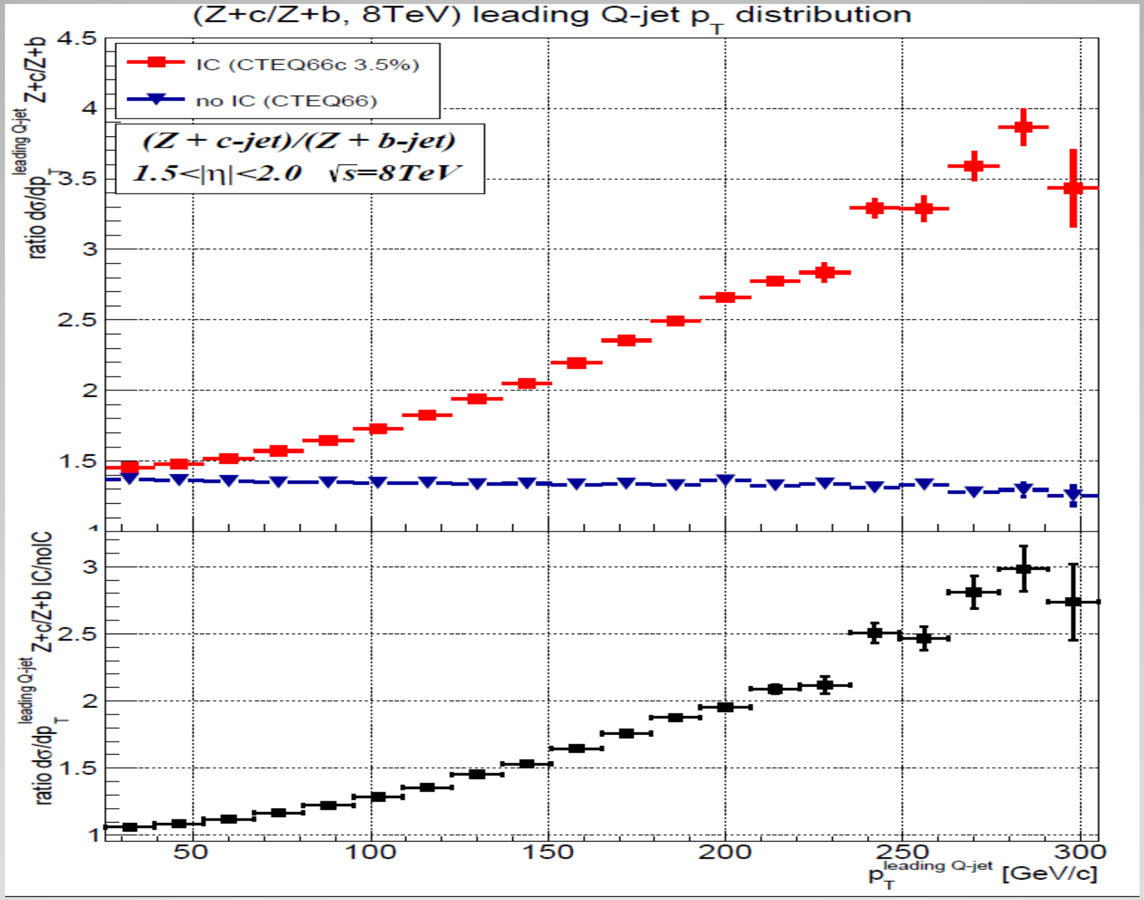
PP -> Z+c(b)+X





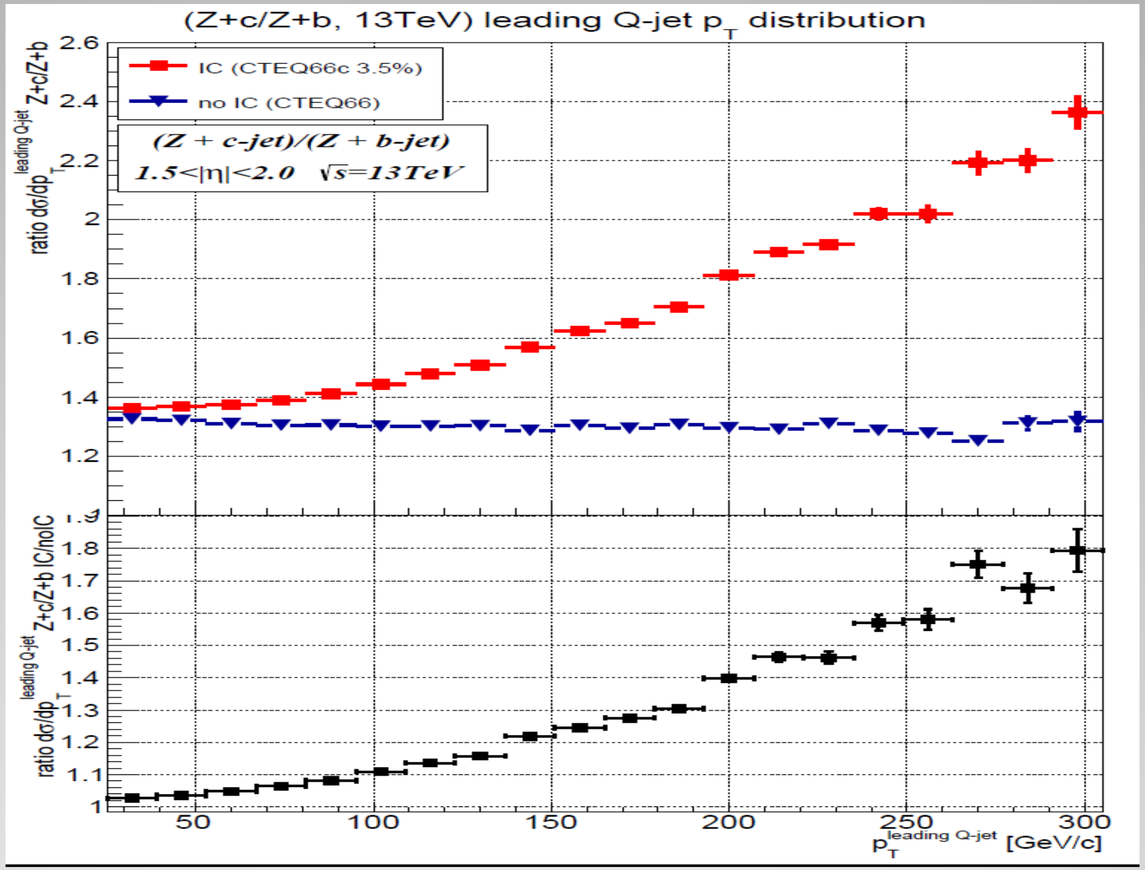
Ratio $\sigma_{pp}(Z+c)/\ \sigma_{pp}(Z+b)$ as a function of the *IC* probability w at p_T^Z >100 GeV/c (bottom dash-dotted line), p_T^Z >200 GeV/c middle dotted line) and p_T^Z >300 GeV/c (top solid line). Left : $s^{1/2}$ = 8 TeV; right: $s^{1/2}$ = 13 TeV.

PP -> 8 TeV at $s^{1/2}$ = 8 TeV



Ratio σ_{pp}(Z+c)/ σ_{pp}(Z+b) as a function of p_T of leading jet. Top: with the *IC* probability w = 3.5 % (red points) and without *IC* (blue points). Bottom: ratio of red points to blue ones.

PP -> Z + c(b) +X at $s^{1/2}$ = 13 TeV



Ratio $\sigma_{pp}(Z+c)/\ \sigma_{pp}(Z+b)$ as a function of p_T of leading jet.
Top: with the *IC* probability w = 3.5 % (red points) and without *IC* (blue points).
Bottom: ratio of red points to blue ones.

SUMMARY

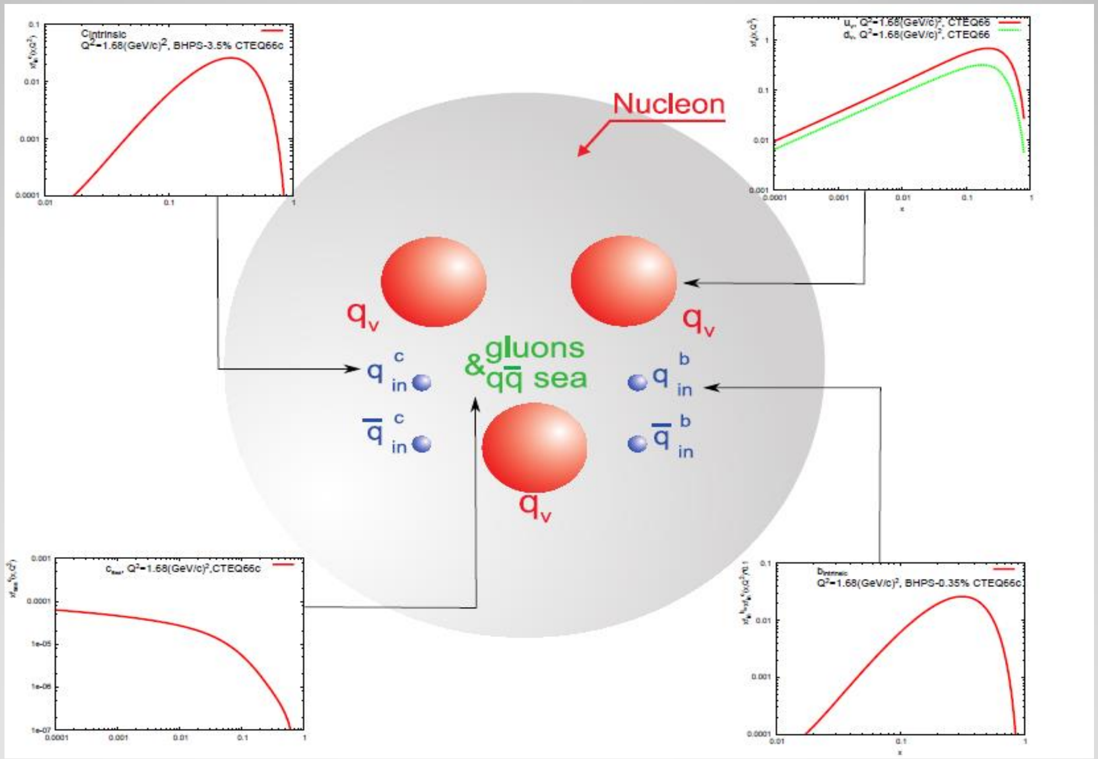
1. We suggest to measure the ratio of cross sections $(Z/\gamma + c)/(Z/\gamma + b)$ as a function of p_T^Z or $p_T^{leadingQ}$
2. At $p_T^Z > 300$ GeV/c the *IC* signal is maximum and this ratio becomes about 2.5-2.8 at the *IC* probability $w = 3.5$ %.
3. We calculate this ratio within the k_T –factorization of QCD as a function of *w* at different intervals of p_T^Z , when $0<w<3.5\%$.
4. We estimate the uncertainty of our predictions, it is less than 10%.
5. The similar predictions are made within the PYTHIA

THANK YOU VERY MUCH FOR YOUR ATTENTION !

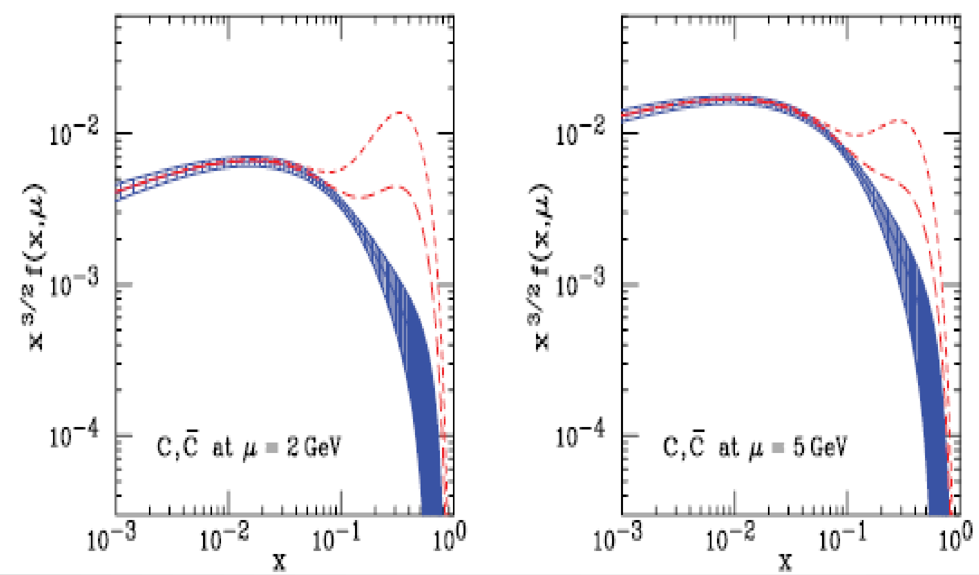
BACK UP

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



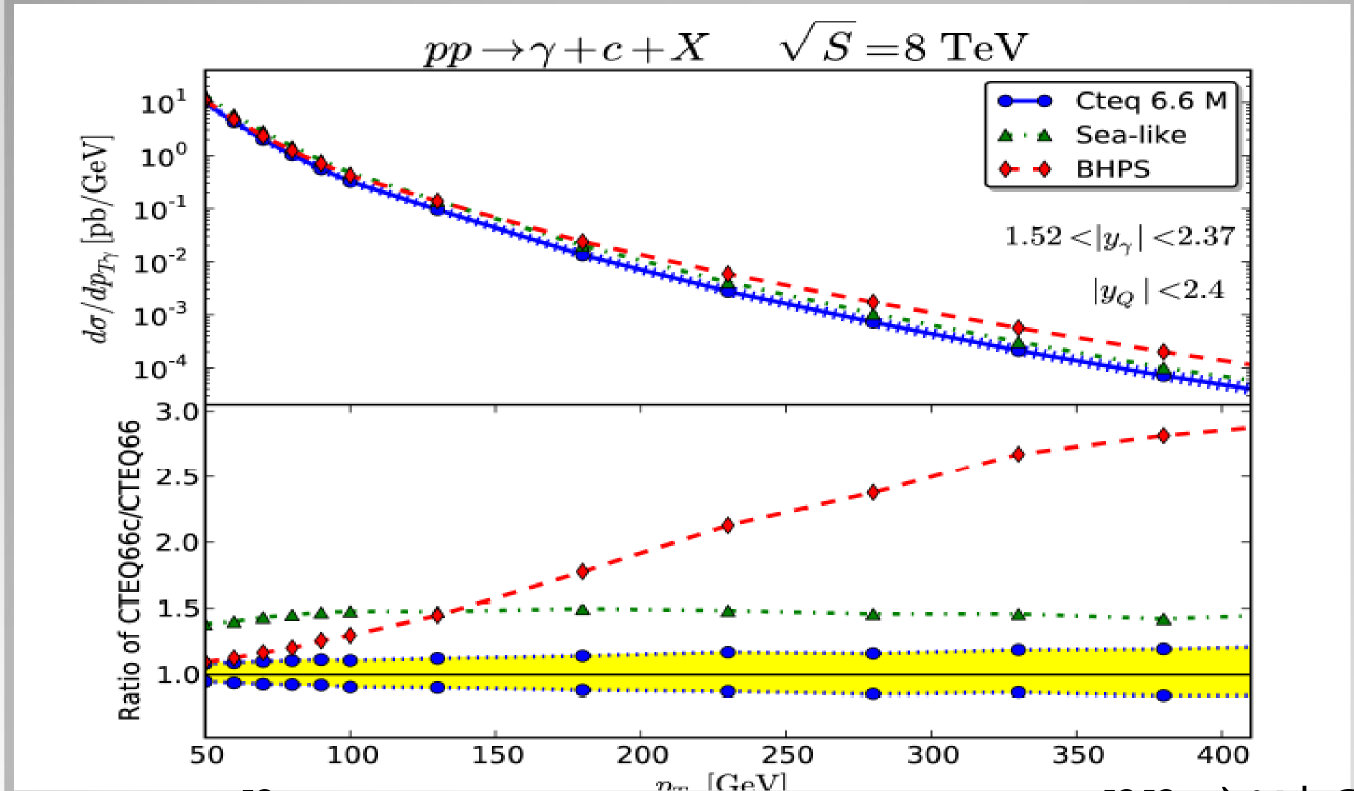
CHARM QUARK DISTRIBUTIONS IN PROTON



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

IC signal in $pp \to \gamma + c(jet) + X$



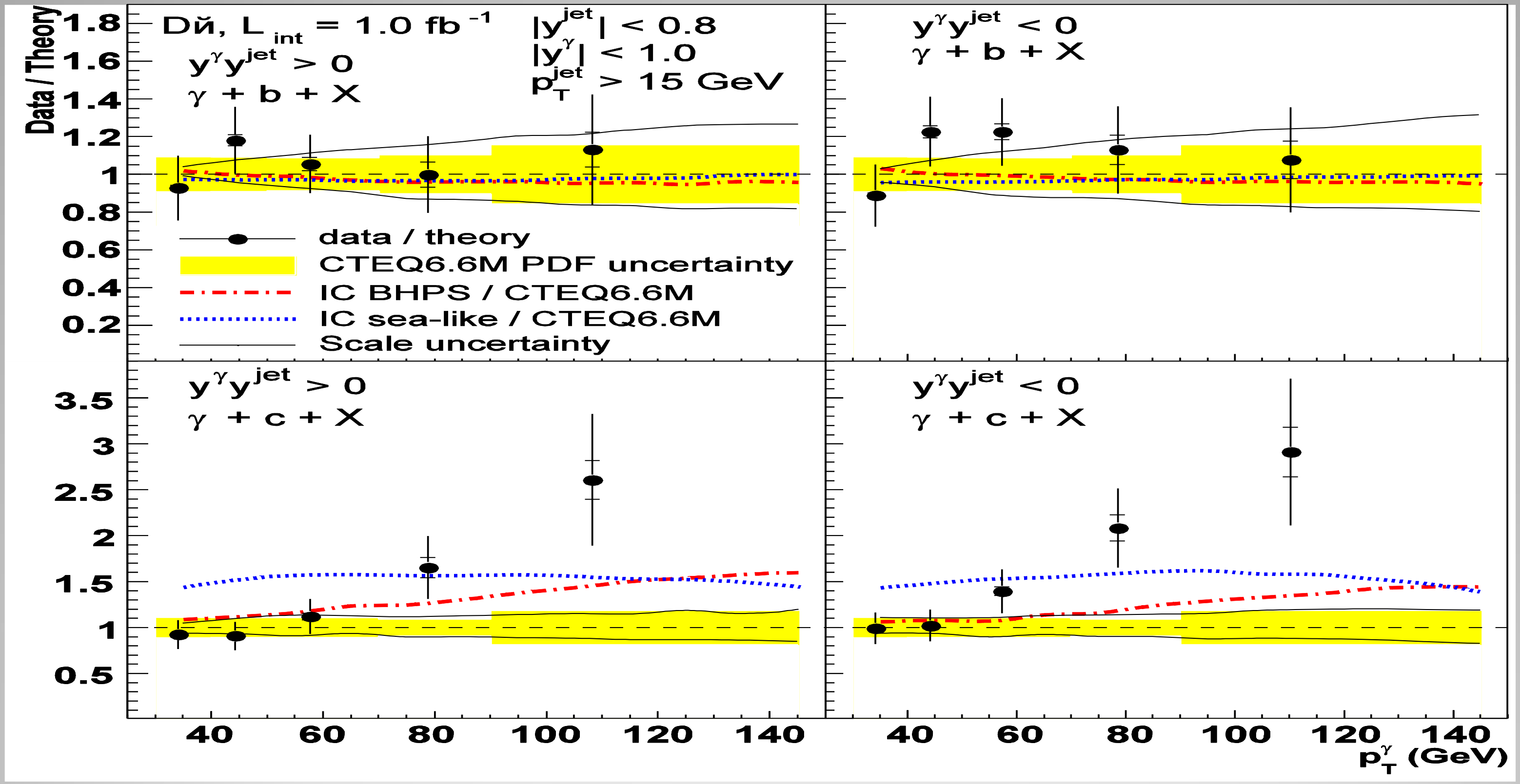
V.A.Bednyakov, M.A.Demichev, G.L., T.Stavreva, M.Stockton, hep-ph/1305.3548

Phys.Lett. B728 (2014) 602.

$p_T -$distribution of photons produced in $pp \to \gamma + c(jet) + X$

The blue line is calculation without the **IC.** The red curve includes the **IC,** its **probability is about 3.5 %** (top). The ratio of spectra with and without the **IC** **The IC signal is about 200%-250% at** $p_T \sim 150-200\,GeV/c$ where the cross section is about 20-80 fb (400-3200 events) and can be measured

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



The data-to-theory ratio of cross sections as a function of p_T^γ for $p\bar{p} \to \gamma + c(b) + X$. There is the **three time excess** of the data above the theory for $\gamma + c$ at $p_T > 150\ GeV/c$. **It stimulates us to study** $pp \to \gamma + c(b) + X$

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

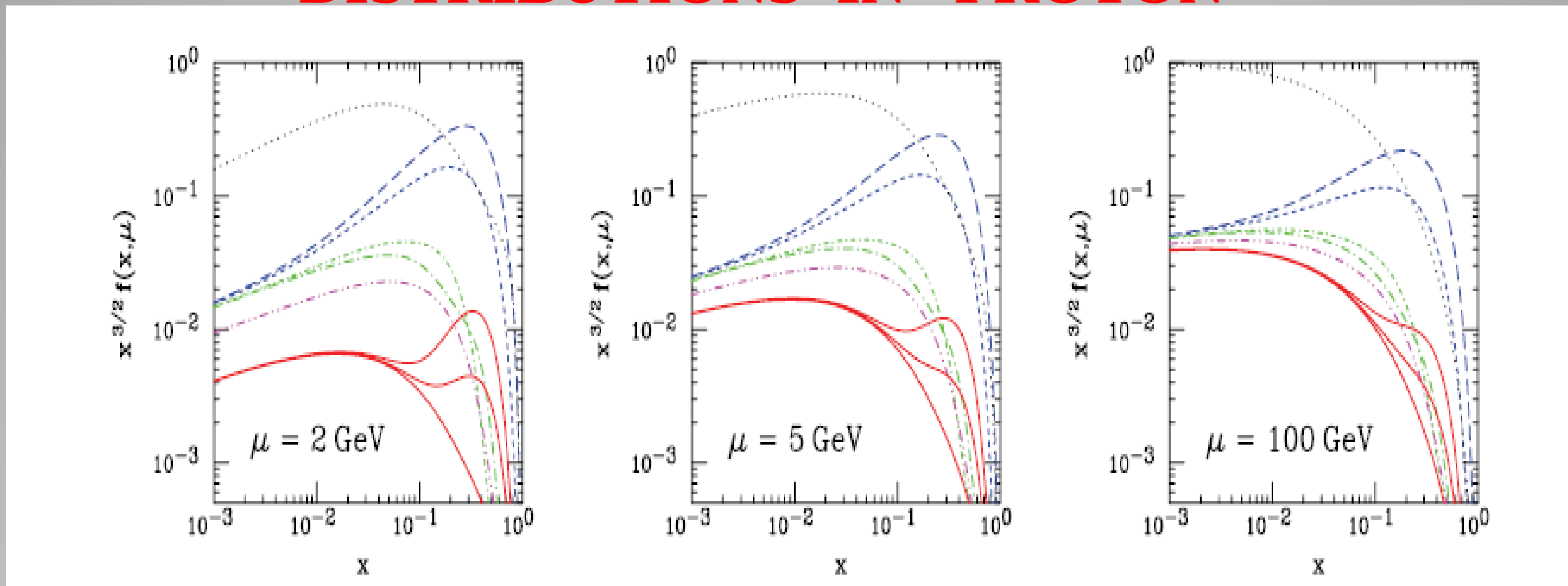
Integrating $P(x_1,\ldots,x_5)$ over $dx_1\ldots dx_4$ and neglecting of all quark masses except the charm quark mass we get

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

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. N_5 determines some probability w_{IQ} to find the Fock state $|uudQ\bar{Q}\rangle$ 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** $0<x_5<1$

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

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

$$x_i^{\min} = \frac{x_T \cot(\frac{\theta}{2})}{2 - x_T \tan(\frac{\theta}{2})}$$

$$x_F \equiv \frac{2p_z}{\sqrt{s}} = \frac{2p_T}{\sqrt{s}}\frac{1}{\tan\theta} = \frac{2p_T}{\sqrt{s}}\sinh(\eta)$$

$$x_i^{min} = \frac{x_R + x_F}{2 - (x_R - x_F)}$$

$$x_R = 2p/\sqrt{s}$$

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.

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

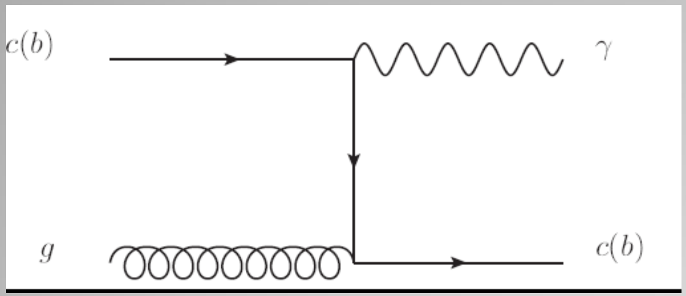


Fig.a. Feynman diagram for the process $c(b) + g \to \gamma + c(b)$

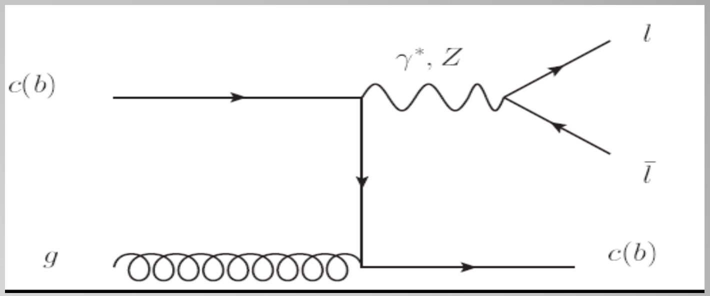


Fig.b. Feynman graph for the process $c(b) + g \to \gamma / Z^0 + c(b)$

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

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

To observe the IC

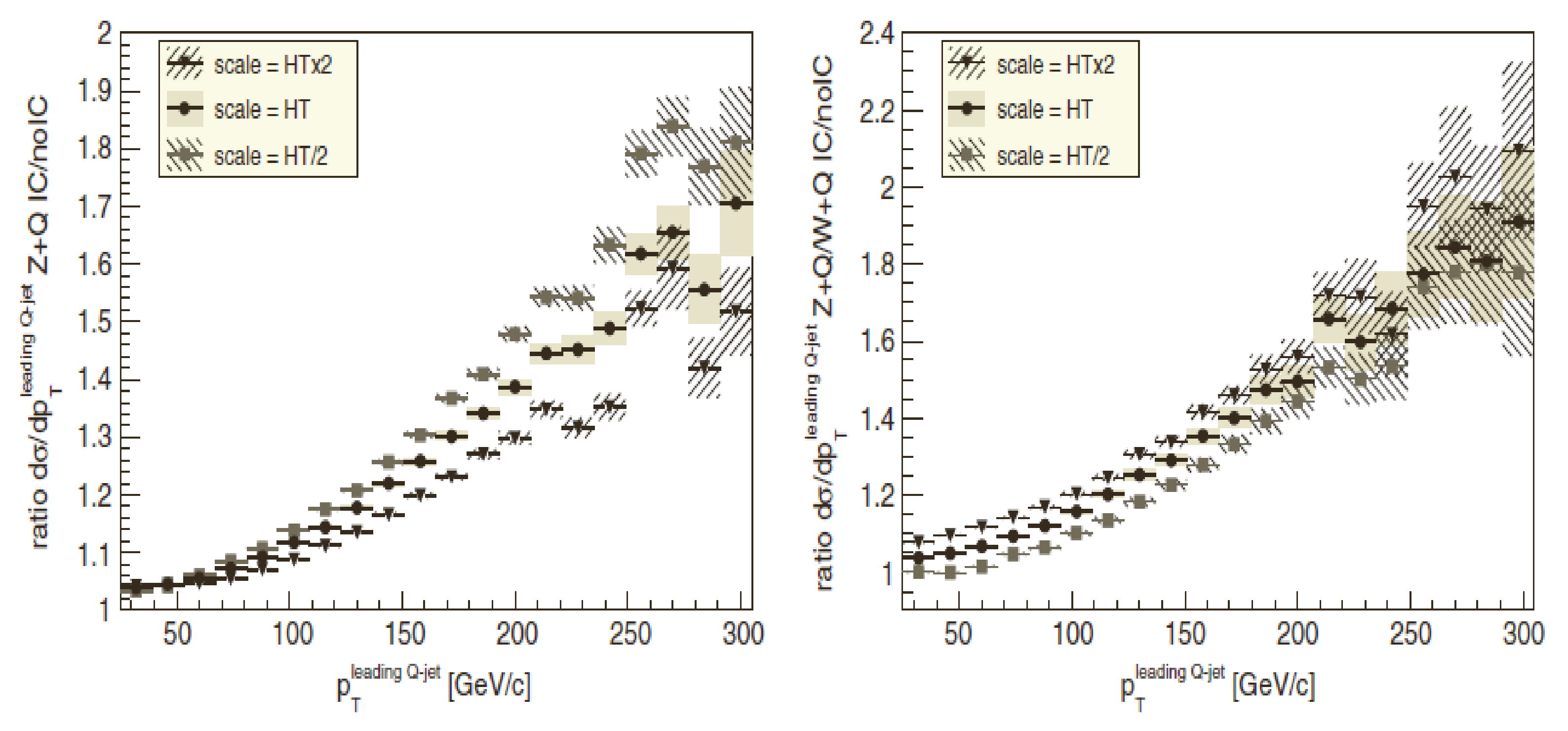
for Fig.a

$$x_c \geq x_F > 0.1$$

for Fig.b

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

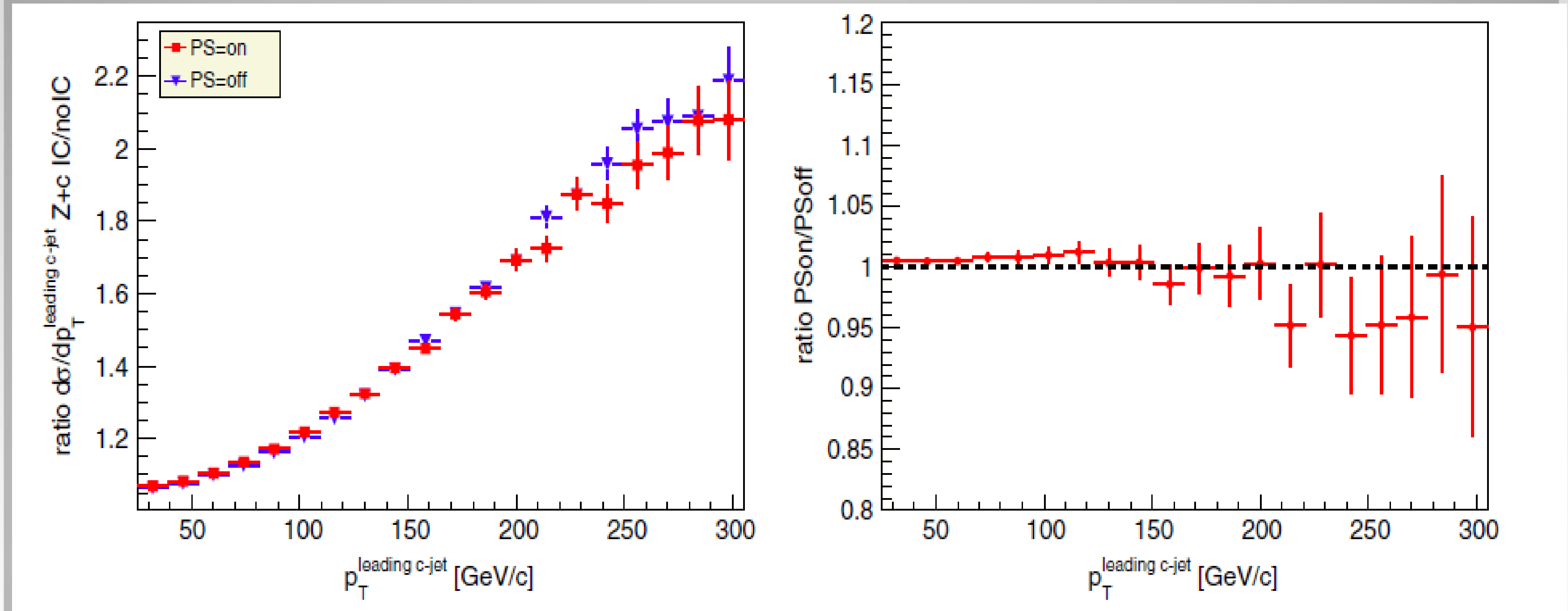
Scale uncertainty for Z+Q and Z+Q/W+Q



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

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

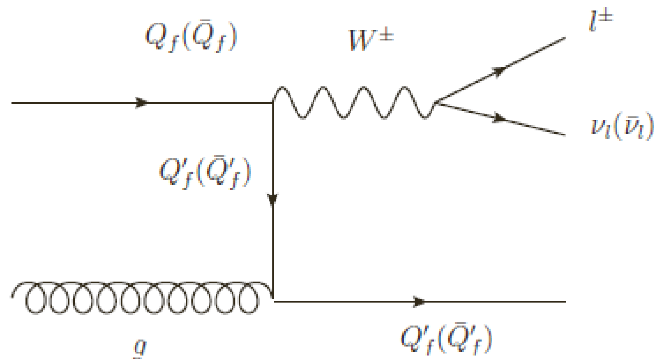
Inclusion of parton shower by Z+Q production in pp at $s^{1/2}$ =8 TeV



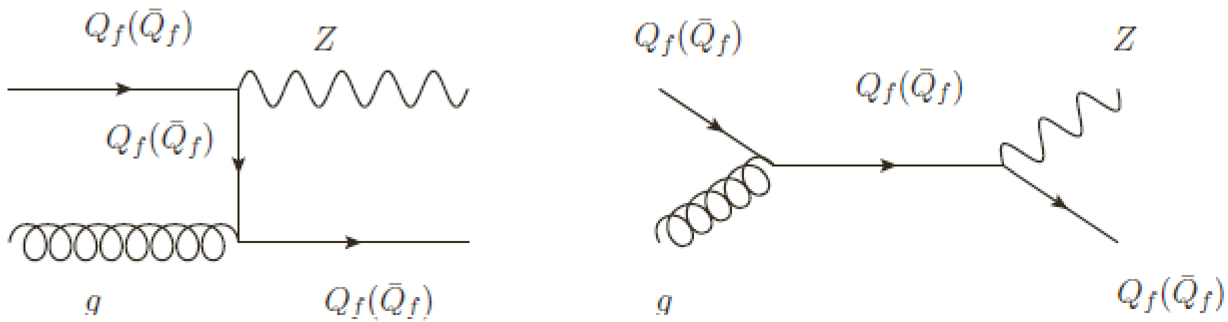
Left: p_T – spectra with parton shower (red points) and without it (blue points) using the PDF of type CTEQ66c (*3.5%* of *IC*)

Right: ratio of red points to blue points

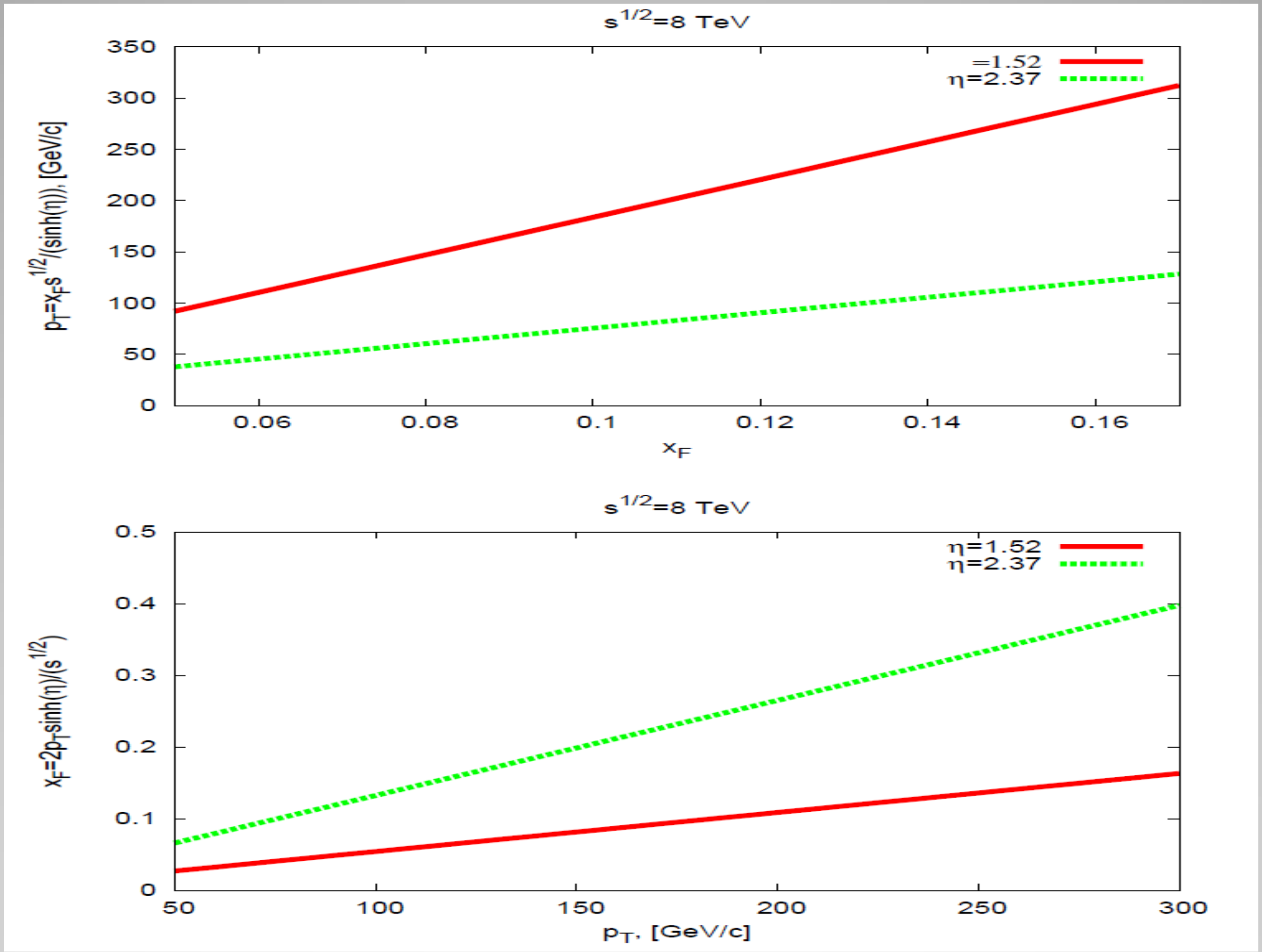
pp →W/Z+heavy flavour jets

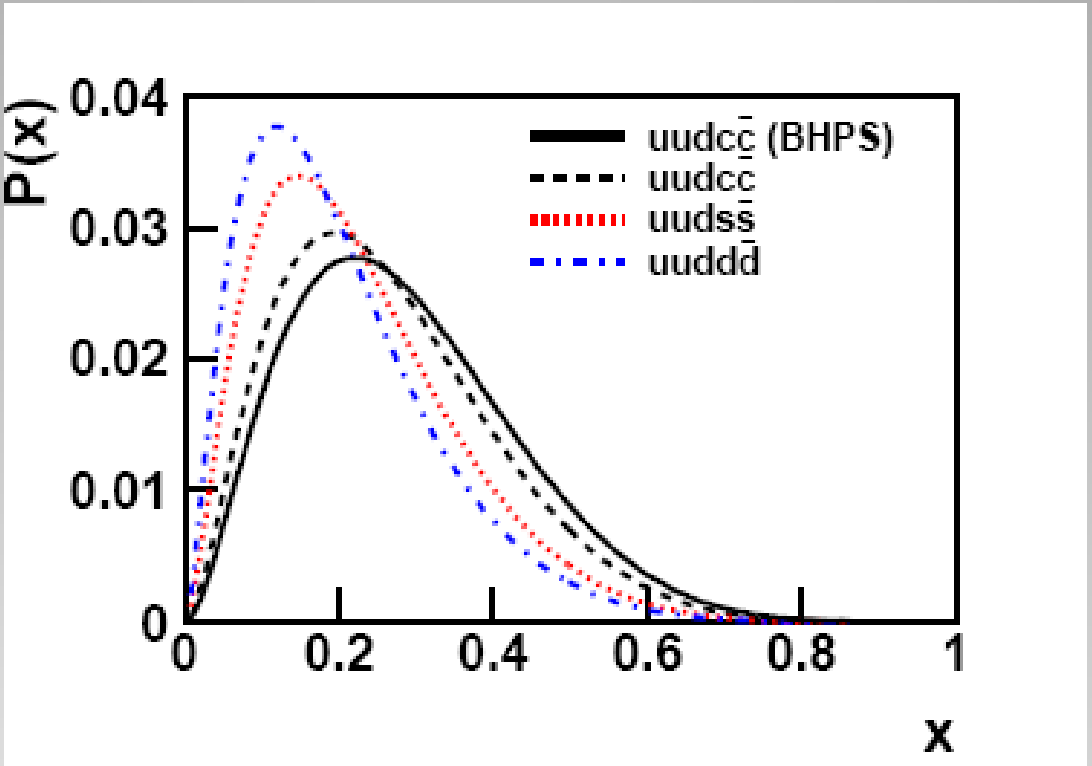


The LO Feynman diagrams for the process $Q_f(\bar{Q}_f)g \to W^\pm Q'_f(\bar{Q}'_f)$, where $Q_f = c.b$ and $Q'_f = b, c$ respectively.

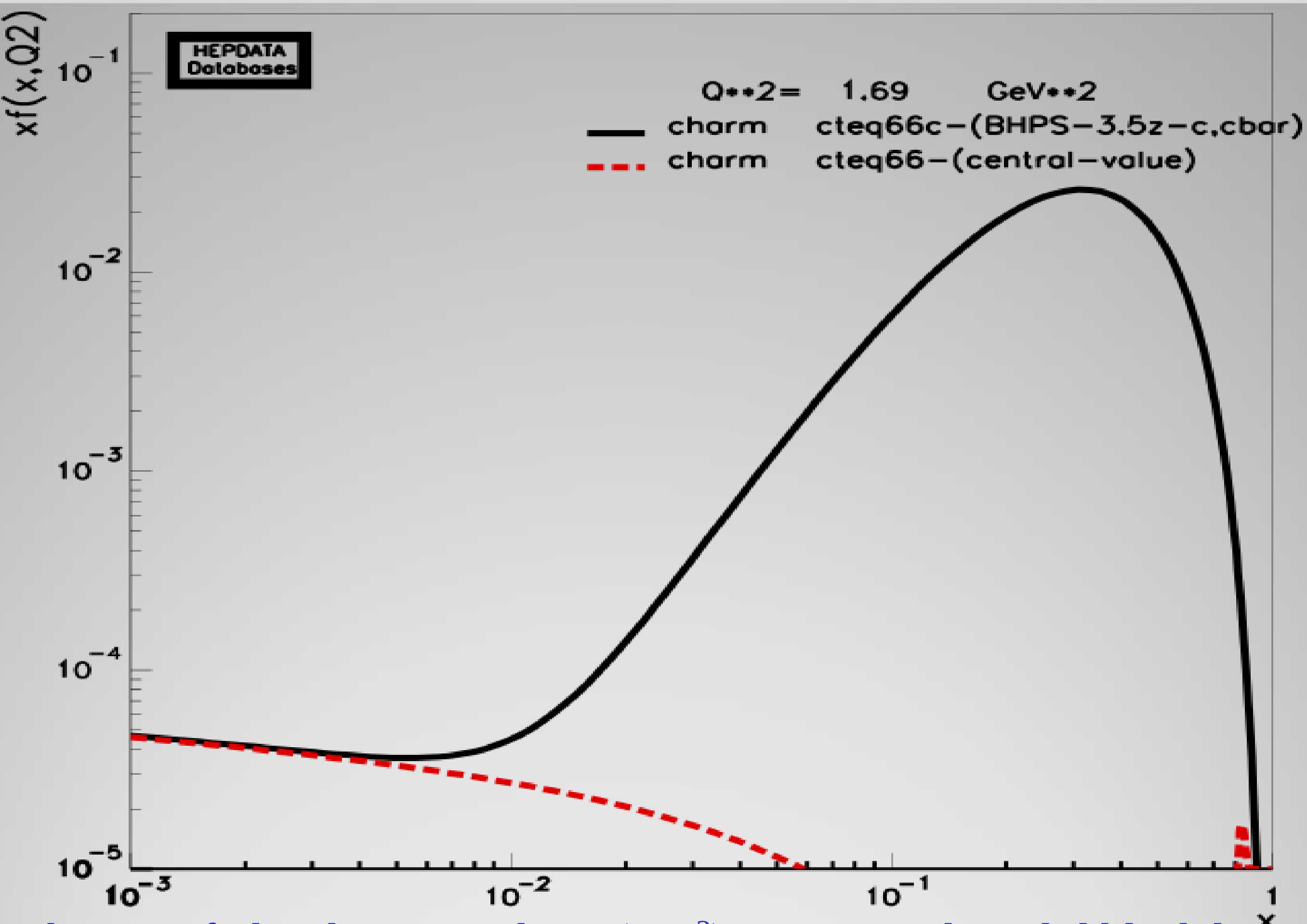


Feynman diagram for the process $Q_f(\bar{Q}_f)g \to ZQ_f(\bar{Q}_f)$

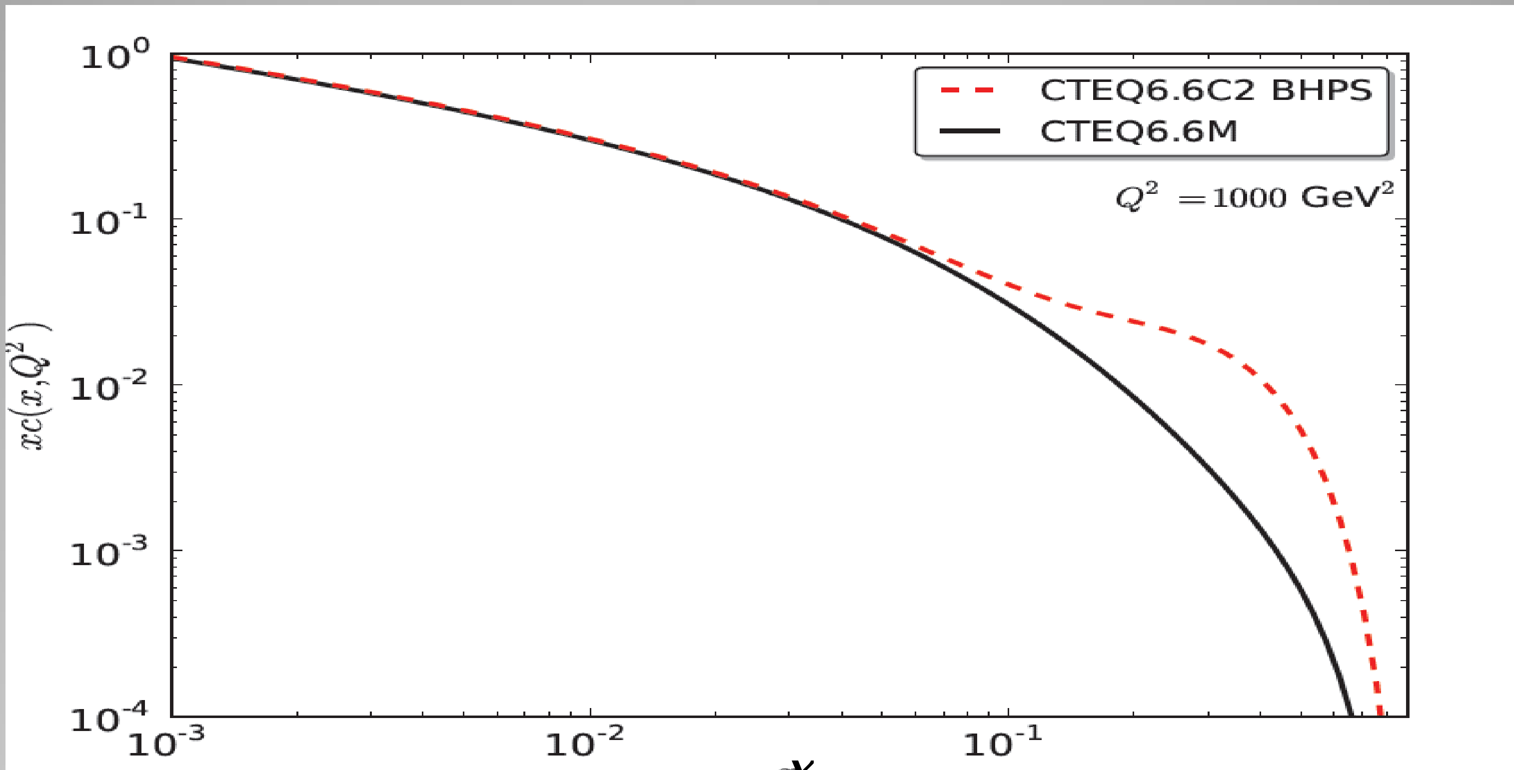

s^1/2=8 TeV
=1.52
η=2.37
p_T=x_F s^1/2/(sinh(η)), [GeV/c]
x_F
s^1/2=8 TeV
η=1.52
η=2.37
x_F=2p_T sinh(η)/(s^1/2)
p_T, [GeV/c]



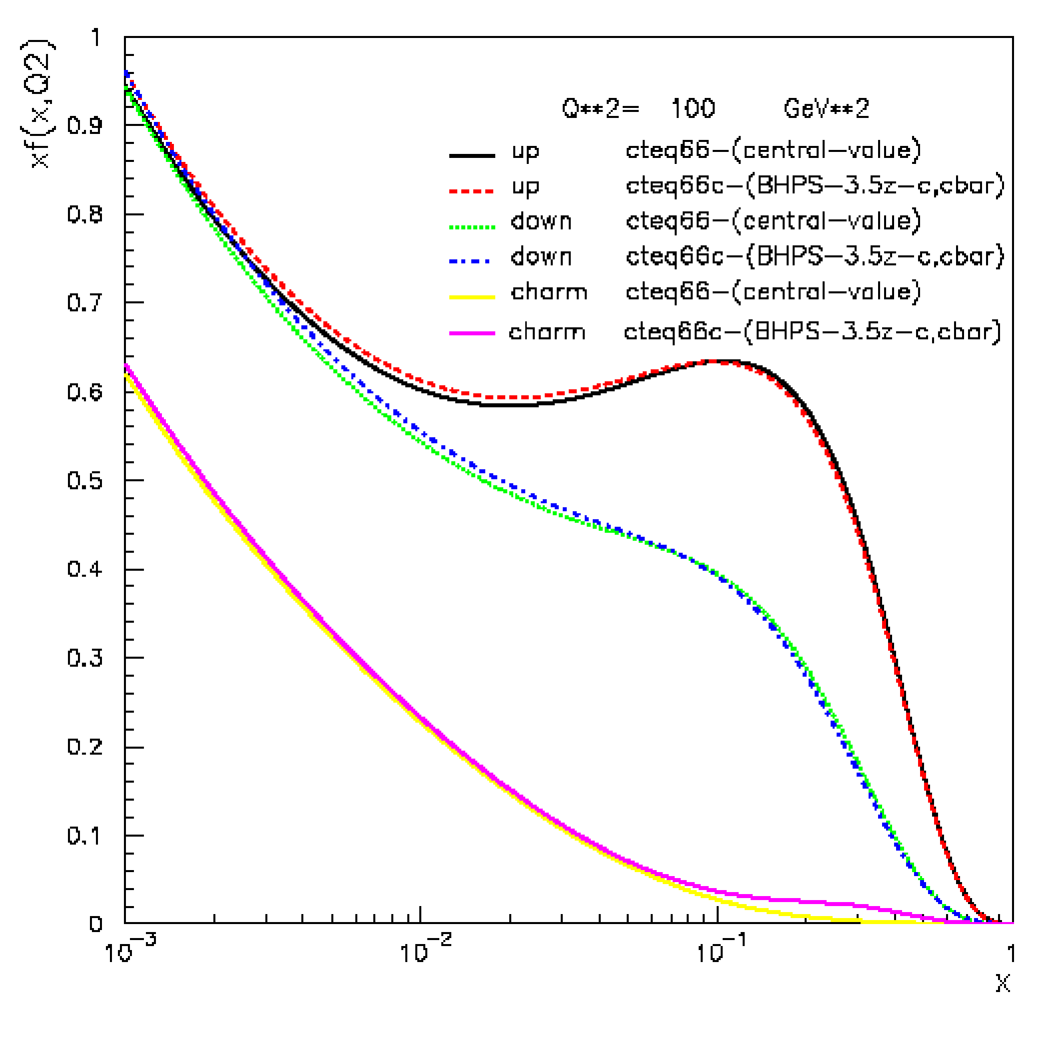
The x-distribution of the intrinsic **Q** calculated within the BHPS model. **There is an enhancement at x > 0.1**
Jen-Chieh Peng & We-Chen Chang, hep-ph/1207.2193.



The x-distribution of the charm quarks $xc(x,Q^2)$ in proton; the solid black line is the IC contribution with its probability about 3.5 %, the dash green curve is the see charm quark contribution xc_{sea} (x,Q^2) at Q^2=1.69 GeV^2. There is enhancement at x>0.1.

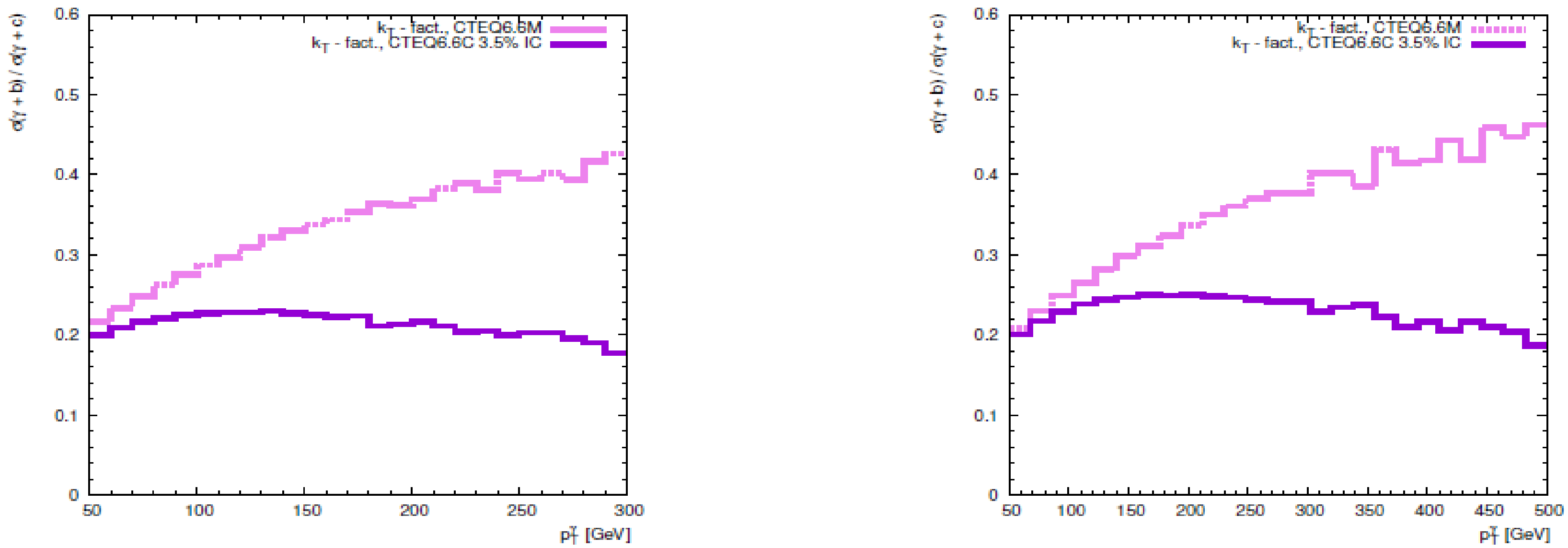


The x-distribution of the charm quarks $xc(x,Q^2)$ in the proton at Q^2=1000 GeV^2 ; the solid black line is the radiatively generated charm density $xc_{rg}(x,Q^2)$ distribution only , whereas the dashed curve is the sum of $xc_{rg}(x,Q^2)$ and the intrinsic charm density $xc_{in}(x,Q^2)$ with its probability about 3.5 %. **There is the sizable enhancement at x > 0.1**.



xf(x,Q2)
Q**2= 100 GeV**2
up cteq66–(central–value)
up cteq66c–(BHPS–3.5z–c,cbar)
down cteq66–(central–value)
down cteq66c–(BHPS–3.5z–c,cbar)
charm cteq66–(central–value)
charm cteq66c–(BHPS–3.5z–c,cbar)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10^-3
10^-2
10^-1
1
X

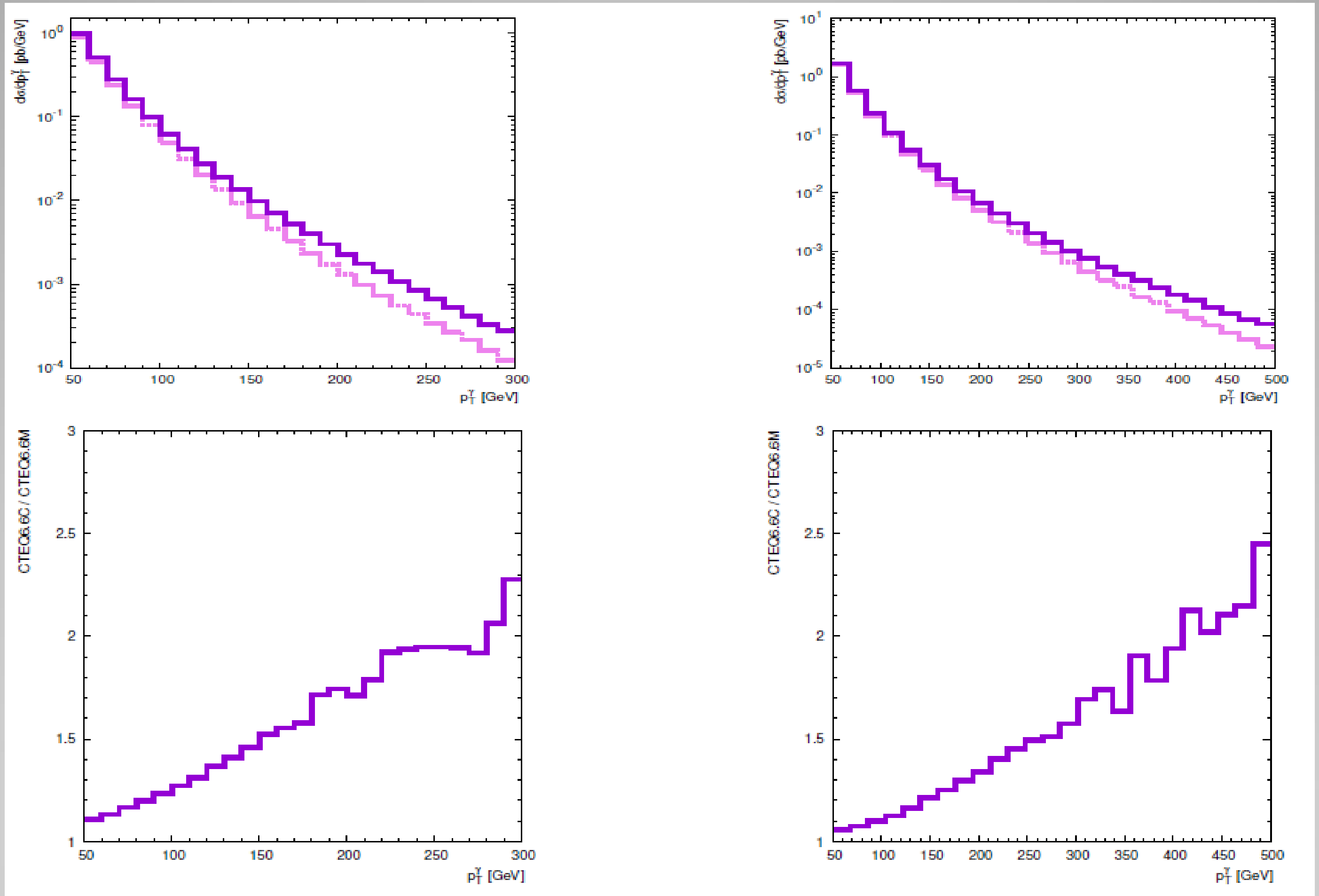
pp -> γ+c(b)+X



The ratio $\sigma(\gamma + b)/\sigma(\gamma + c)$ as a function of the photon transverse momentum at $1.5 < |y^\gamma| < 2.4$, $|y^{\rm jet}| < 2.4$, $p_T^{\rm jet} > 20$ GeV, $\sqrt{s} = 8$ TeV (left panel) and $\sqrt{s} = 13$ TeV (right panel)

One can see a grow of this ratio by increasing of p_T^γ, when the intrinsic charm contribution (*IC*) in PDF is ignored. This ratio is approximately flat or slowly decreasing when the *IC* about 3.5 % is included. That is an additional *IC* signal, which could be measered at ATLAS.

pp ->γ+D +X*



Top: p_T –spectra of a photon at $s^{1/2}$ =8 Tev (left) and 13 TeV(right)
Bottom: ratio of p_T –spectra with IC (3.5%) and without it at 8 TeV (left) and 13 TeV (right).