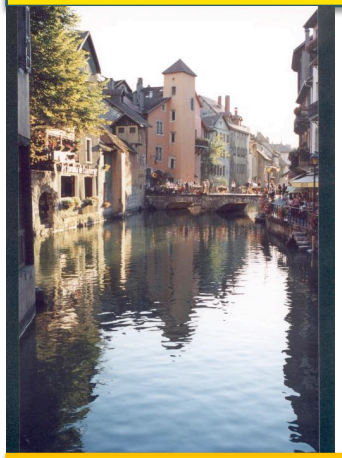


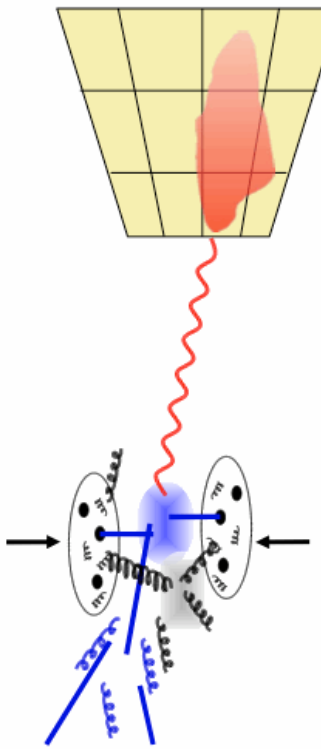
How well can isolated photons contrain the proton PDFs ?

Raphaëlle ICHOU (*)
Subatech, Nantes

Workshop on Nuclear PDFs
Annecy - February 22-23th 2010

(*) Collaboration work with
David d'Enterria, François Arleo

Outline

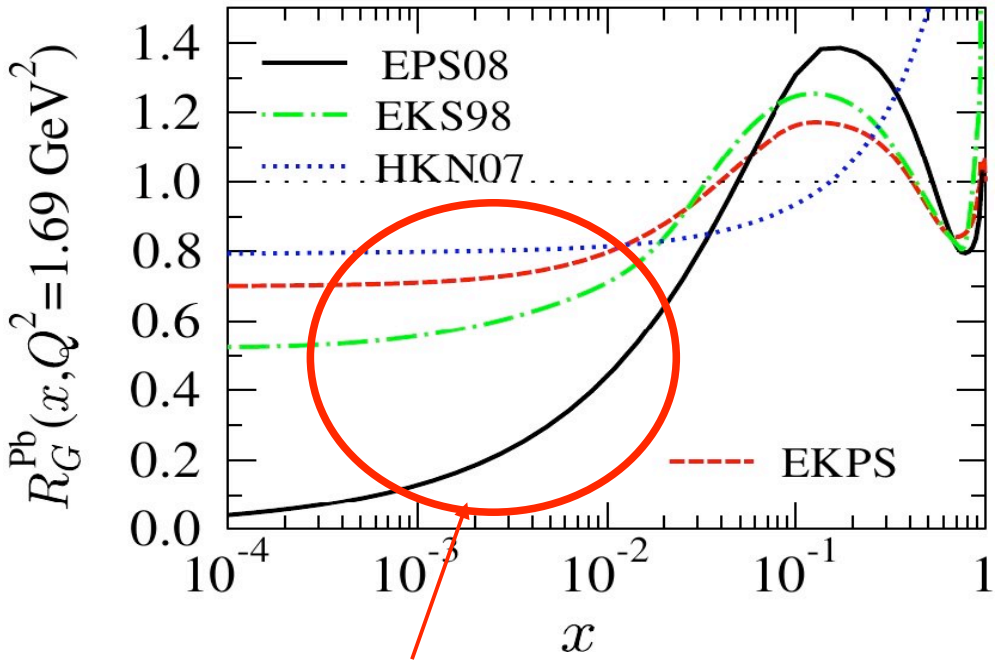


1. Physics motivations
    1. Nuclear and proton PDFs
    2. Prompt photons
    3. Isolated prompt photons
2. Comparison between Tevatron data and NLO p-QCD predictions
3. Sensitivity of isolated photons spectra to PDFs in p-p at LHC mid-rapidity
    1. Cross-section dependence on PDFs
    2. Theoretical uncertainties
4. Sensitivity of isolated photons spectra to PDFs in p-p at LHC forward-rapidity
    1. Cross-section dependence on PDFs
    2. Theoretical uncertainties

Nuclear PDFs (gluon)

- Current knowledge of low-x gluons:

K.Eskola et al. JHEP 0807 (08)102



Very large uncertainties below $x \sim 10^{-2}$!

BUT, xG(x,Q2) of the proton has its own uncertainties still, not shown!

Motivations

Nuclear and proton PDF

Prompt photons

Isolated prompt photons

Tevatron vs NLO p-QCD predictions

Predictions at LHC(y=0)

X-section PDFs Th. Uncertainties

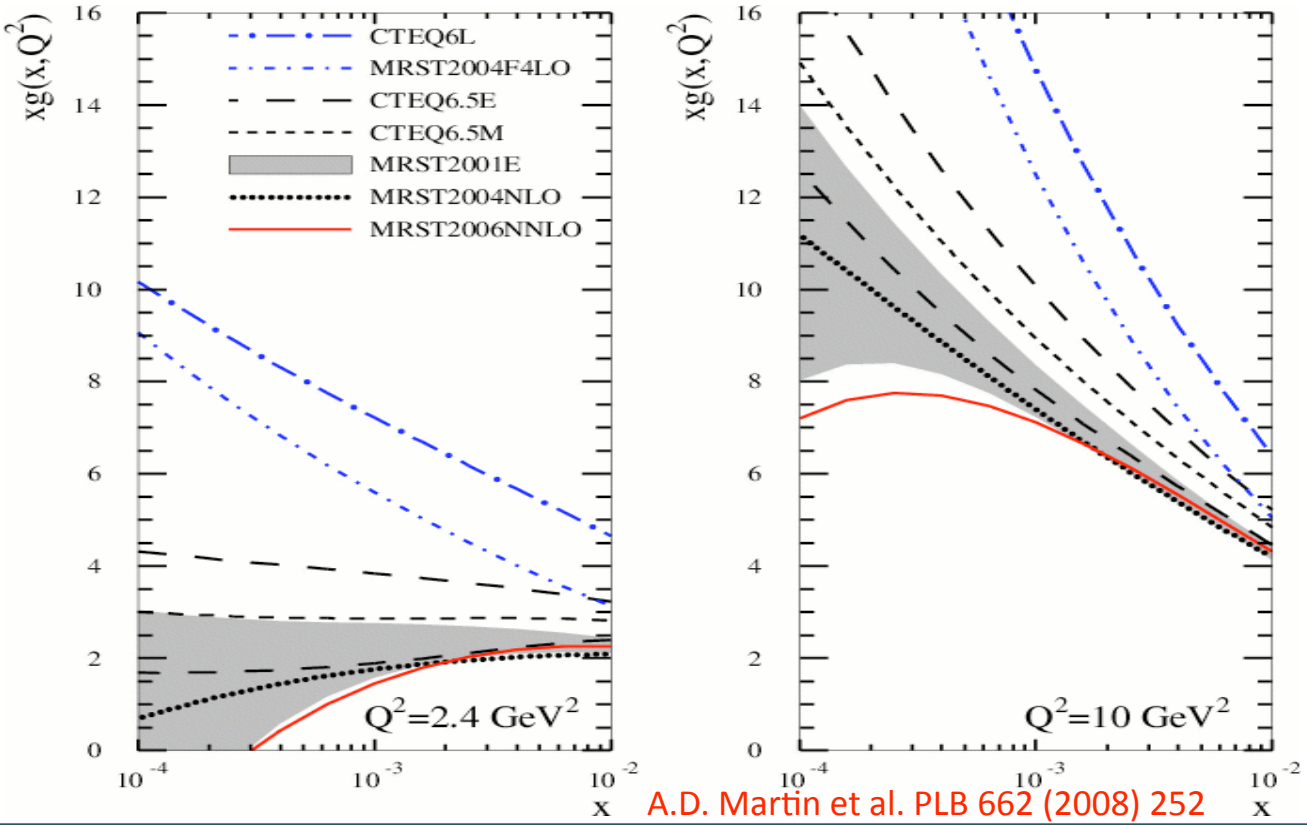
Predictions at LHC(y=4)

Proton PDFs (gluon)

- Most of our current knowledge of low-x gluons comes indirectly from e^- proton F_2 "scaling violations":

$$\frac{\partial F_2(x,Q^2)}{\partial \ln(Q^2)} \approx \frac{10\alpha_s(Q^2)}{27\pi} xg(x,Q^2)$$

- Large uncertainties below $x \sim 10^{-2}$ at moderate Q^2 :



A.D. Martin et al. PLB 662 (2008) 252

Motivations

Nuclear and proton PDF

Prompt photons

Isolated prompt photons

Tevatron vs NLO p-QCD predictions

Predictions at LHC(y=0)

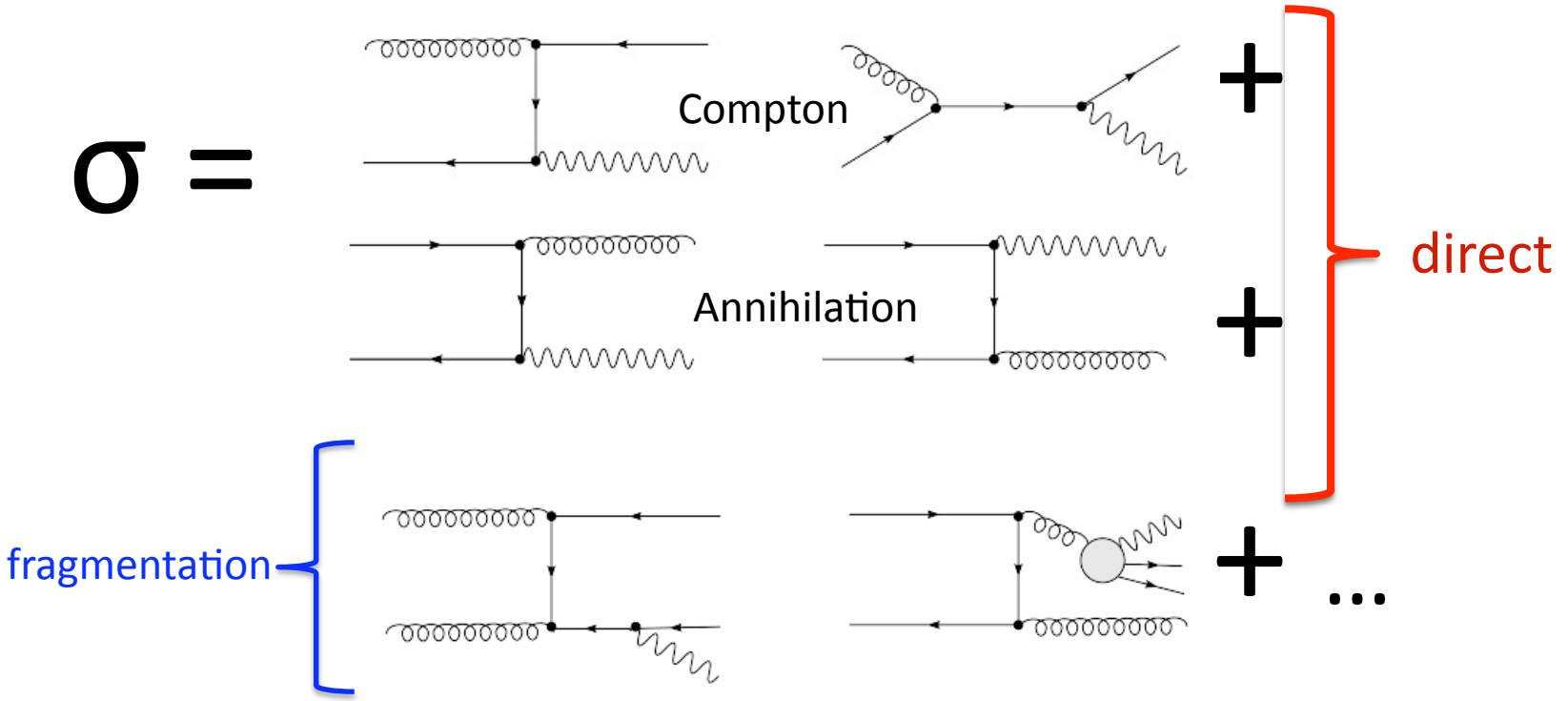
X-section PDFs Th uncertainties

Predictions at LHC(y=4)

X-section PDFs Th uncertainties

Prompt photon production in p-p

Prompt photons are produced directly in the hard scattering or from the fragmentation of a parton into a photon



Motivations

Nuclear and proton PDF

Prompt photons

Isolated prompt photons

Tevatron vs NLO p-QCD predictions

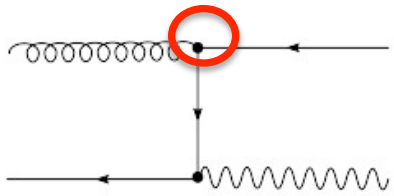
Predictions at LHC(y=0)

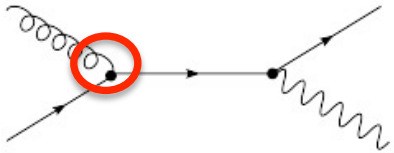
X-section PDFs Th uncertainties

Predictions at LHC(y=4)

X-section PDFs Th uncertainties

Motivation : the gluon PDF

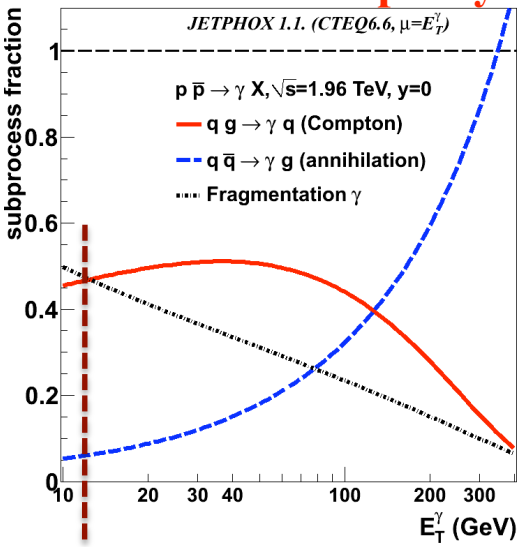




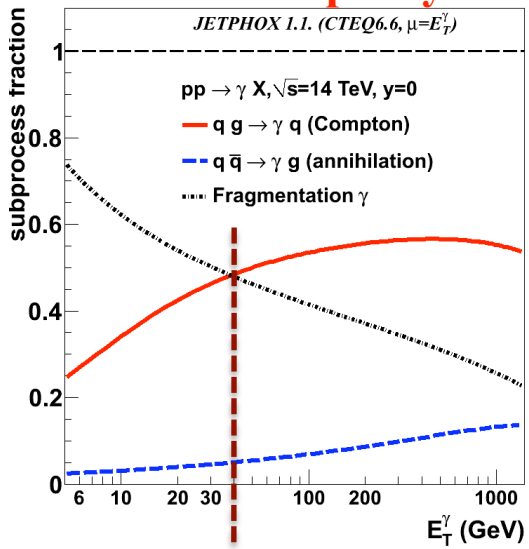
Compton channel :
- information on g(x, Q^2)
-dominate the cross-section :
~ from 13 to 150 GeV (Tevatron)
~ from 35 GeV (LHC mid-rapidity)

But since 1998, no photon data is included in the PDF fits.

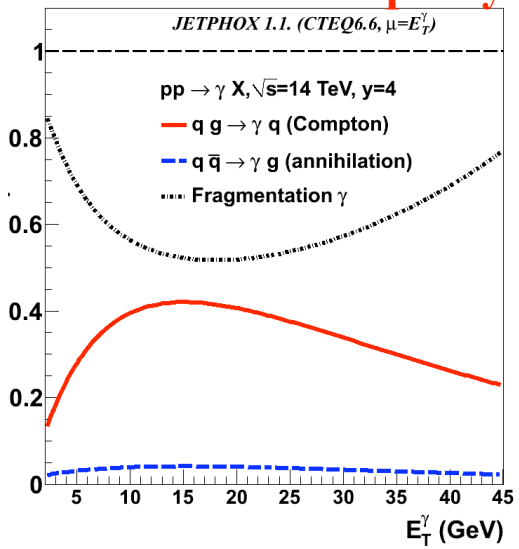
Tevatron mid-rapidity



LHC mid-rapidity

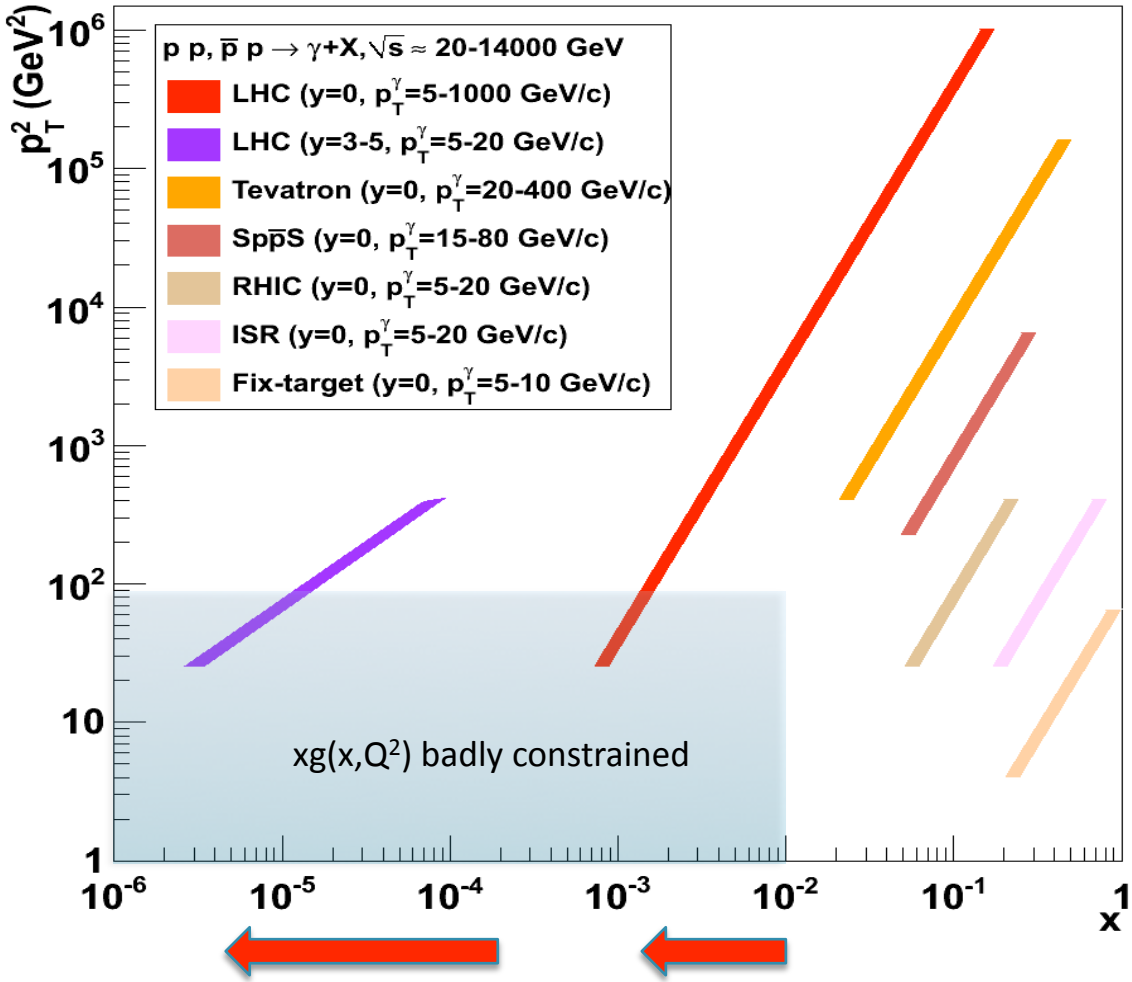


LHC forward-rapidity



Motivations
Nuclear and proton PDF
Prompt photons
Isolated prompt photons
Tevatron vs NLO p-QCD predictions
Predictions at LHC(y=0)
X-section PDFs Th uncertainties
Predictions at LHC(y=4)
X-section PDFs Th uncertainties

(x,Q^2) kinematical plane probed by γ



$$x \approx \frac{p_T}{\sqrt{s}} e^{\pm y}$$

$$Q^2 \approx p_T^2$$

@LHCb forward-rapidity : photon production probes the $g(x,Q^2)$ down to $x = 10^{-5}$

@LHC mid-rapidity : photon production probes values of x 20 times smaller than at Tevatron

Motivations

Nuclear and proton PDF

Prompt photons

Isolated prompt photons

Tevatron vs NLO p-QCD predictions

Predictions at LHC(y=0)

X-section PDFs Th uncertainties

Predictions at LHC(y=4)

X-section PDFs Th uncertainties

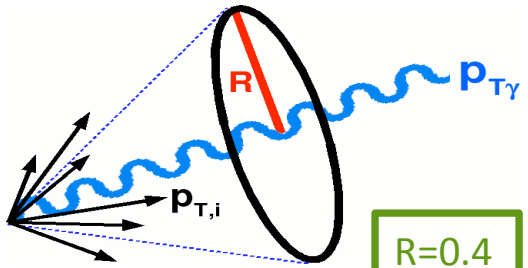
Isolated prompt photons

Why ? - To suppress the background of secondary photons coming from the hadron decays (mainly π^0 , η mesons)

- To reduce fragmentation photons & enhance direct

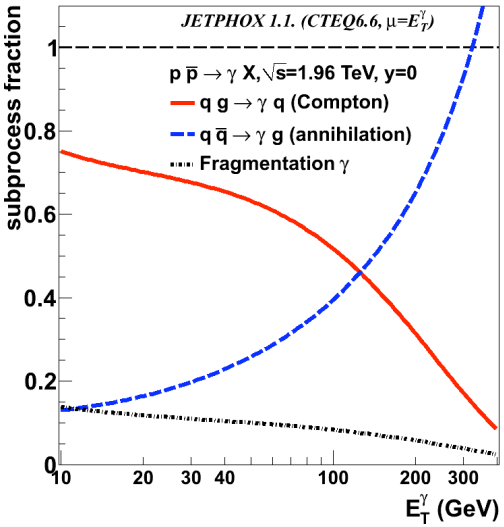
A photon is isolated if the sum of the p_T of the hadrons in a cone of radius $R=\sqrt{(\Delta\eta^2 + \Delta\Phi^2)}$ around γ direction is smaller than a fraction ε of the photon p_T

$$\sum_i p_{T_i} \leq \varepsilon . p_{T_\gamma}$$

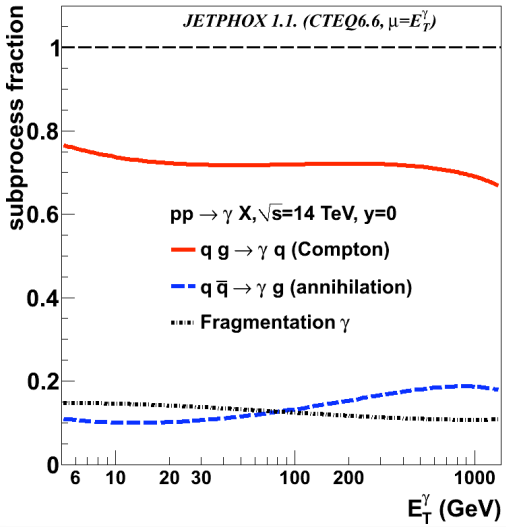


R=0.4
ε=0.1

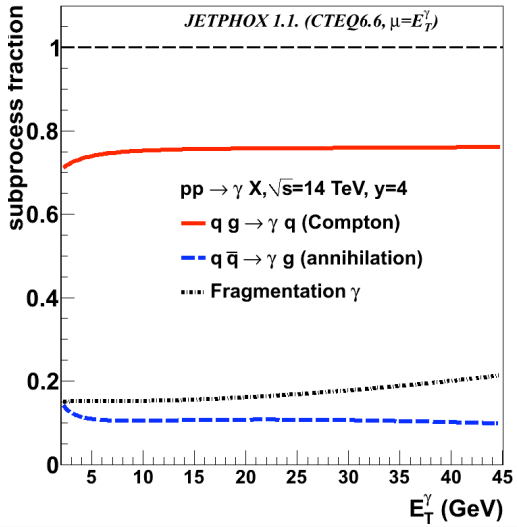
Tevatron mid-rapidity



LHC mid-rapidity



LHC forward-rapidity



Motivations

Nuclear and proton PDF

Prompt photons

Isolated prompt photons

Tevatron vs NLO p-QCD predictions

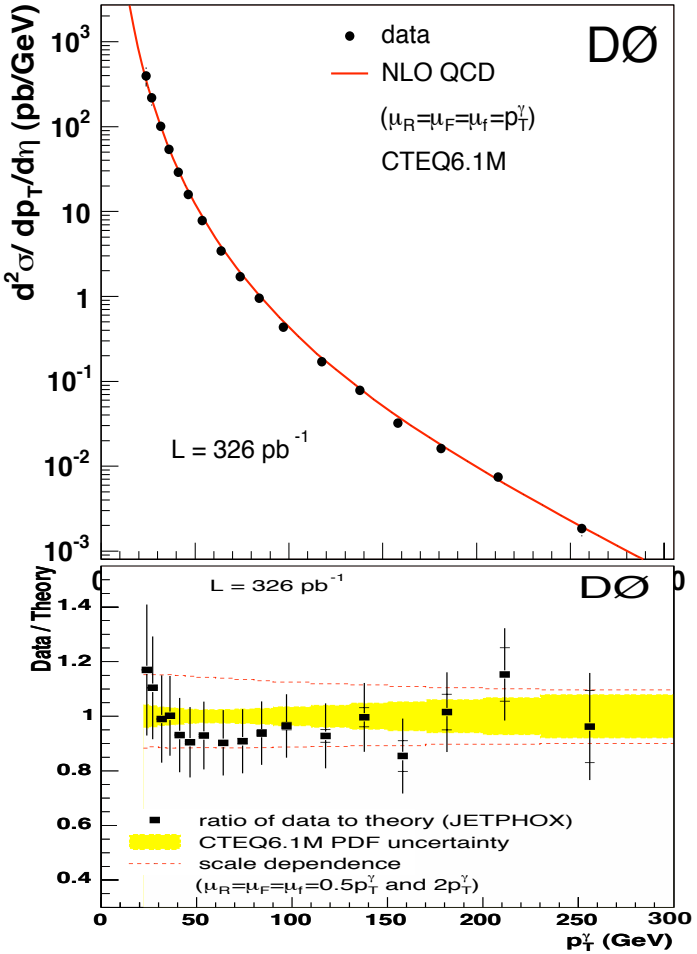
Predictions at LHC(y=0)

X-section PDFs Th uncertainties

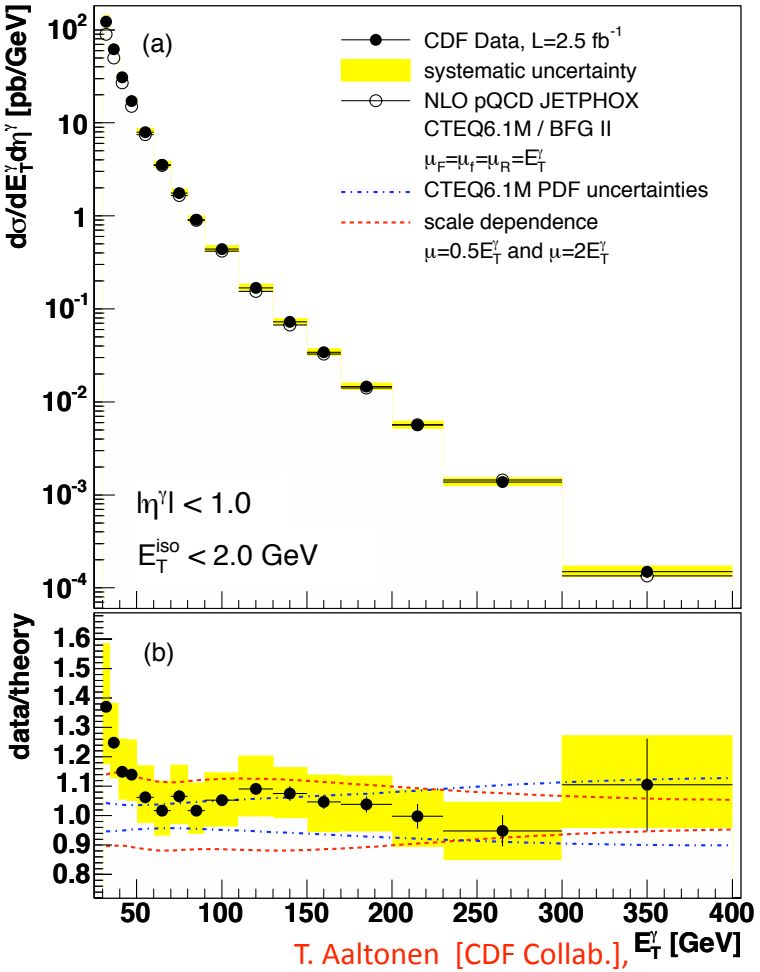
Predictions at LHC(y=4)

X-section PDFs Th uncertainties

Tevatron data vs NLO pQCD predictions



D0 Collab.], PLB 639 (2006) 15



T. Aaltonen [CDF Collab.], arXiv:0910.3623

Good agreement NLO/data with CTEQ6.1M.
(within moderate exp. and theoretical uncertainties)

Motivations

Nuclear and proton PDF

Prompt photons

Isolated prompt photons

Tevatron vs NLO p-QCD predictions

Predictions at LHC(y=0)

X-section PDFs Th uncertainties

Predictions at LHC(y=4)

X-section PDFs Th uncertainties

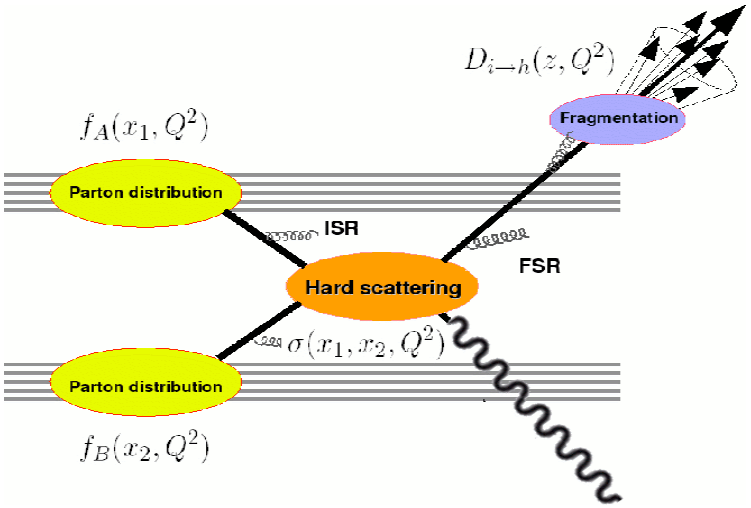
Prompt γ : NLO pQCD calculations

- pQCD NLO calculations with JETPHOX MC

  http://wwwlapp.in2p3.fr/lapth/PHOX_FAMILY/

- pQCD collinear factorization:

$$d\sigma_\gamma =$$



- Ingredient I: PDFs

  Interfaced via LHAPDF: CTEQ6.6,MSTW08,NNPDF1.2

- Ingredient II: FFs : BFG parton->γ parametrization

Motivations

Nuclear and proton PDF

Prompt photons

Isolated prompt photons

Tevatron vs NLO p-QCD predictions

Predictions at LHC(y=0)

X-section PDFs

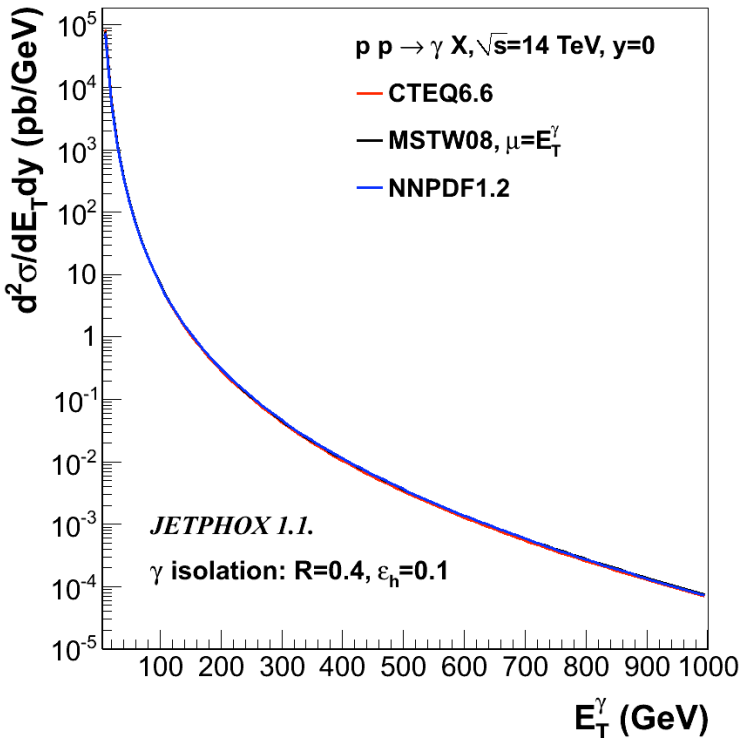
Th uncertainties

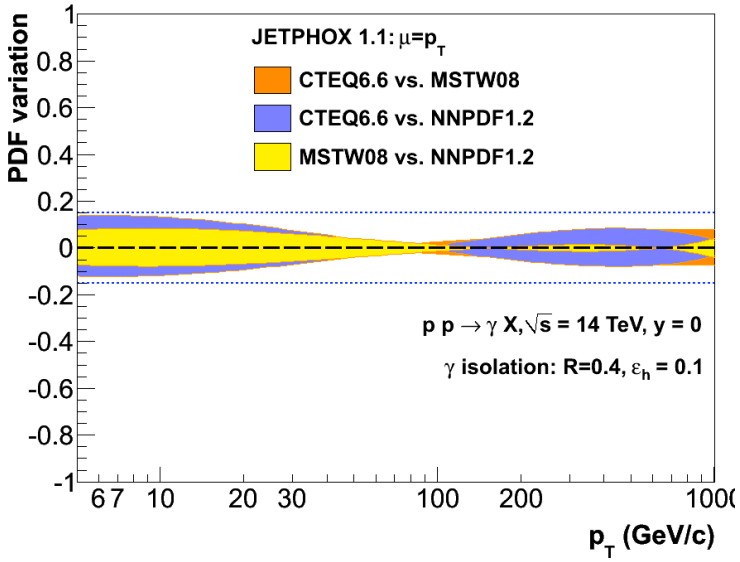
Predictions at LHC(y=4)

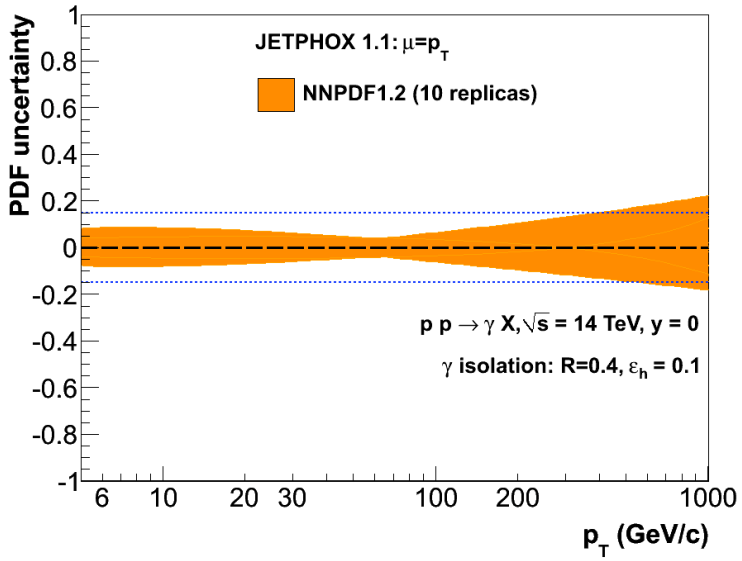
X-section PDFs

Th uncertainties

LHC y=0: Cross section dependence on PDFs







Up to ~ 15% variation of photon yields depending on PDFs below p_T~15 GeV/c.

Similar PDF uncertainties within one single PDF parametrization.

Motivations

Nuclear and proton PDF

Prompt photons

Isolated prompt photons

Tevatron vs NLO p-QCD predictions

Predictions at LHC(y=0)

X-section PDFs

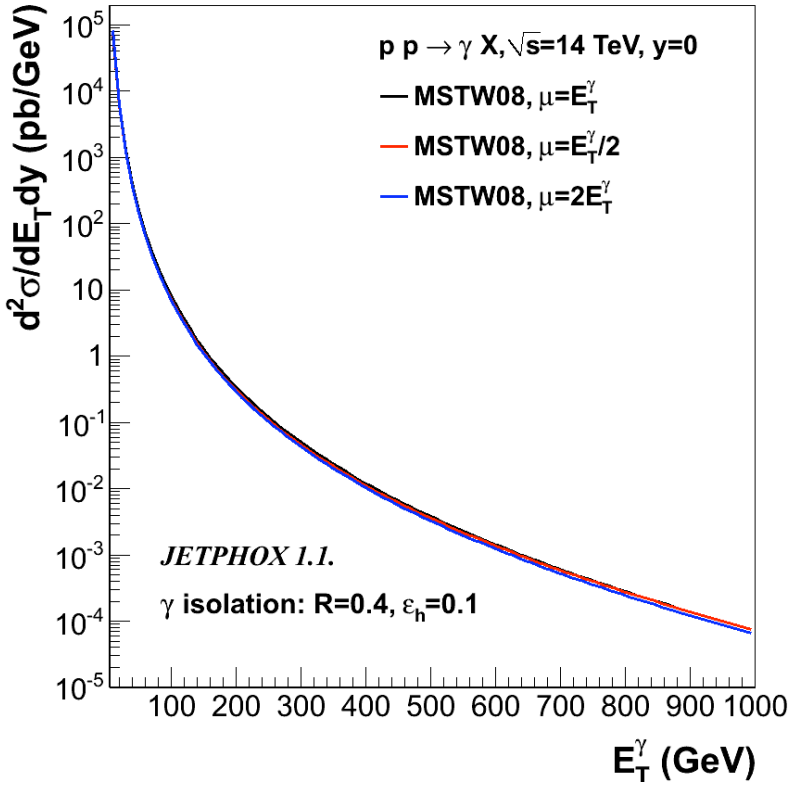
Th uncertainties

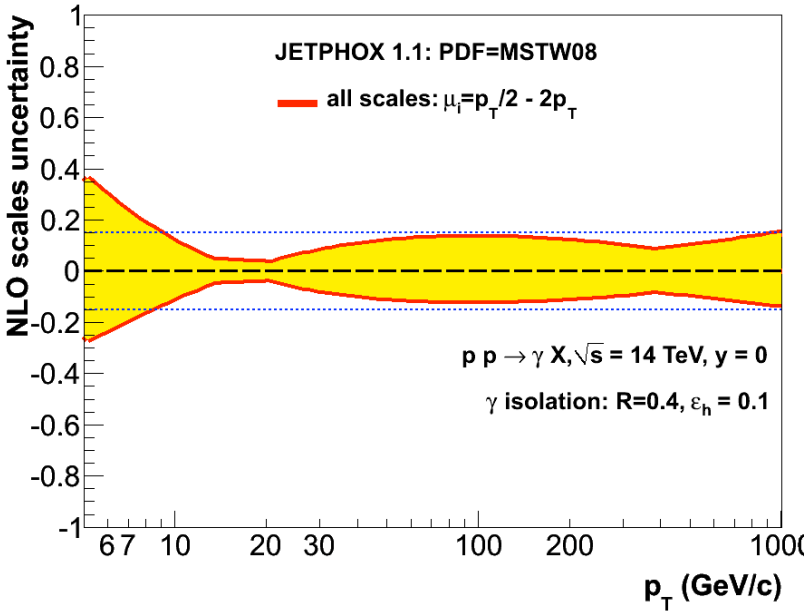
Predictions at LHC(y=4)

X-section PDFs

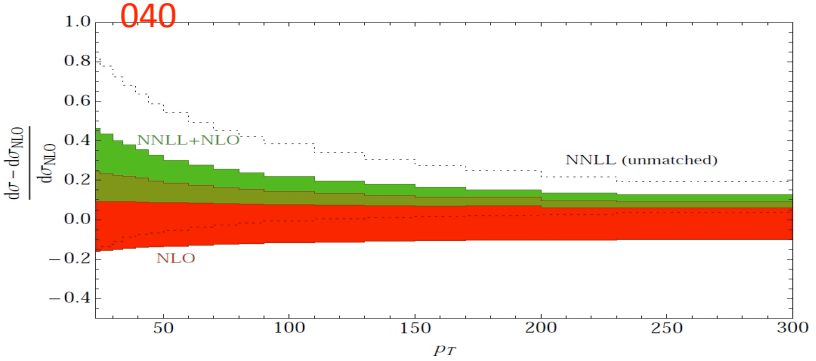
Th uncertainties

LHC y=0 : Theoretical uncertainties (scales)





T. Becher, M. D. Schwartz, JHEP 1002 (2010) 040



Unfortunately scales uncertainties at NLO are larger than PDFs variations

Improve theoretical calculations at NNLL (twice smaller scale uncertainties)?

Motivations

Nuclear and proton PDF
Prompt photons
Isolated prompt photons

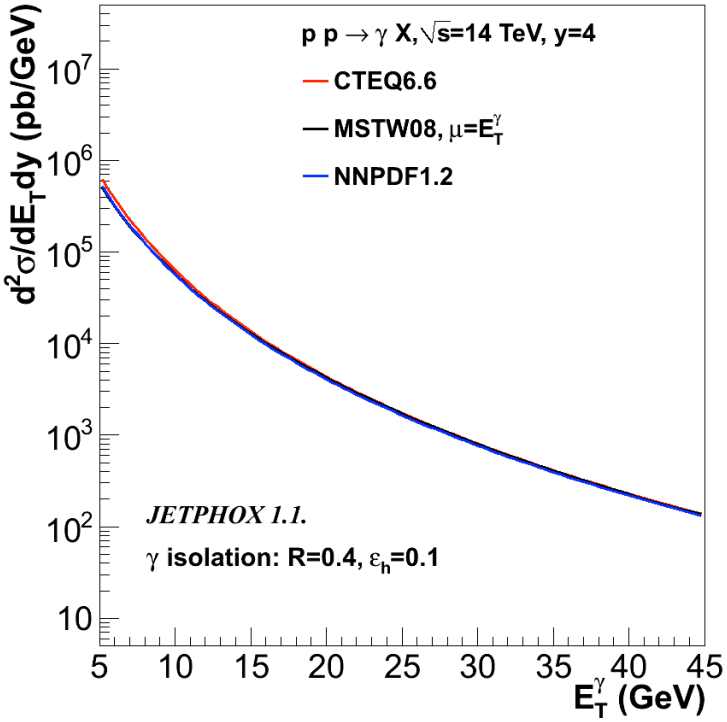
Tevatron vs NLO p-QCD predictions

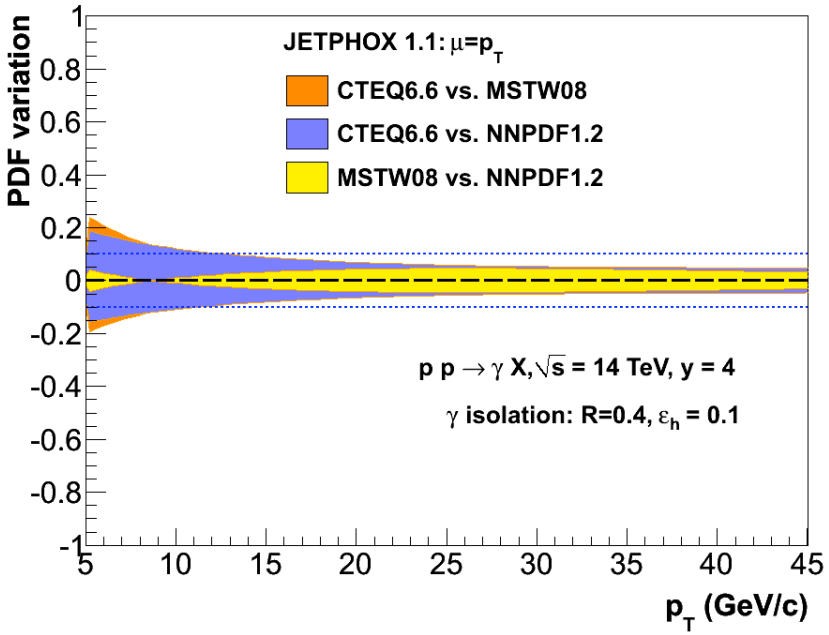
Predictions at LHC(y=0)

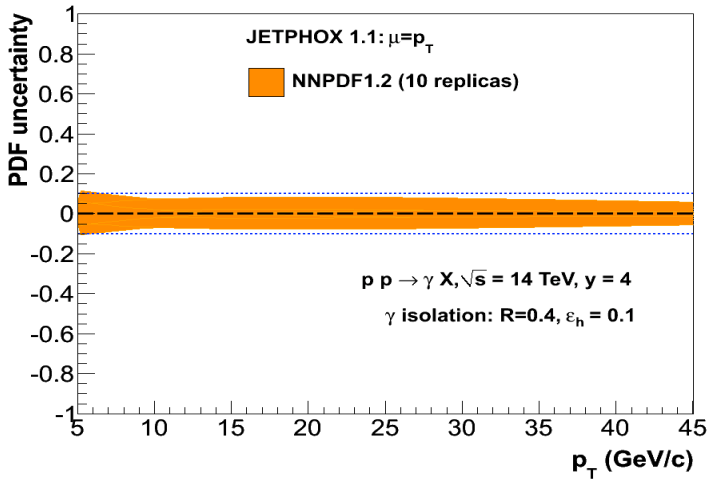
X-section PDFs
Th. Uncertainties

Predictions at LHC(y=4)

LHC y=4: Cross section dependence on PDFs







Up to ~ 20% variation of photon yields depending on PDFs below p_T~15 GeV/c.

PDF uncertainties up to ~15 % within one single PDF parametrization.

Motivations

Nuclear and proton PDF
Prompt photons
Isolated prompt photons

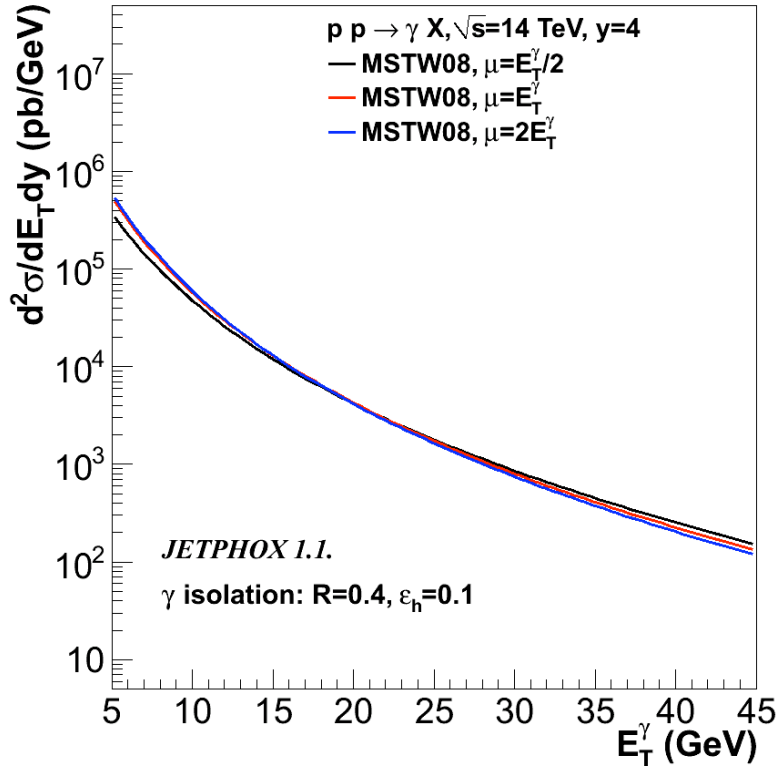
Tevatron vs NLO p-QCD predictions

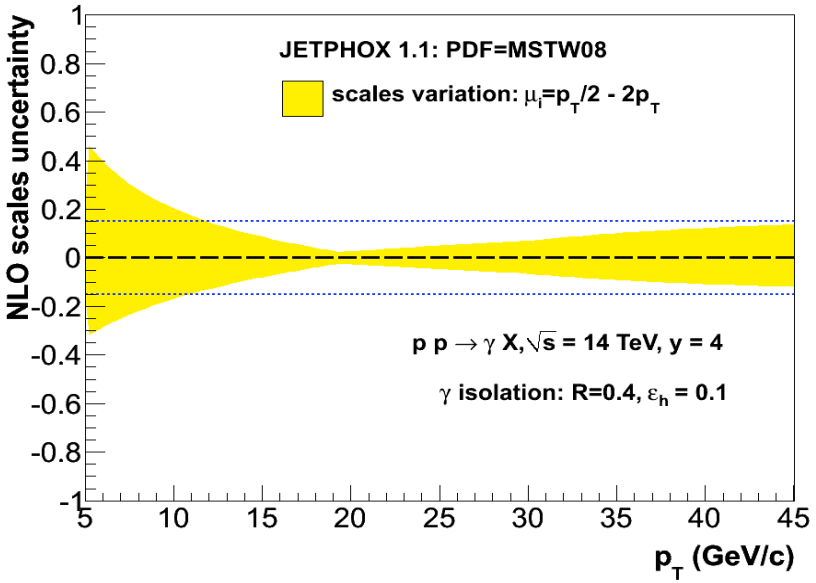
Predictions at LHC(y=0)

X-section PDFs
Th. Uncertainties

Predictions at LHC(y=4)
X-section PDFs
Th uncertainties

LHC y=4: Cross section dependence on scales





Unfortunately scales uncertainties at NLO are larger than PDFs variations

Motivations
Nuclear and proton PDF
Prompt photons
Isolated prompt photons
Tevatron vs NLO p-QCD predictions
Predictions at LHC(y=0)
X-section PDFs
Th. Uncertainties
Predictions at LHC(y=4)
X-section PDFs
Th. Uncertainties

Conclusions && Outlook

1. The measurement of isolated prompt photons spectra is SENSITIVE to the gluon PDFs.

2. But the PDFs uncertainties are always smaller than the theoretical scales uncertainties for LHC mid-rapidity or forward-rapidity.

3. We need to reduce scale uncertainty (+/-20%) in the pQCD calculations to be sensitive to PDF variations (+/-15%)

1. Ongoing studies in ALICE show that we can measure isolated gamma in the p_T range ~[10-100] GeV/c with good stats and syst. uncertainties similar to Tevatron (~15%)
2. Given the larger nuclear PDF uncertainties, it would be interesting to redo those studies for isolated photon in p-A collisions

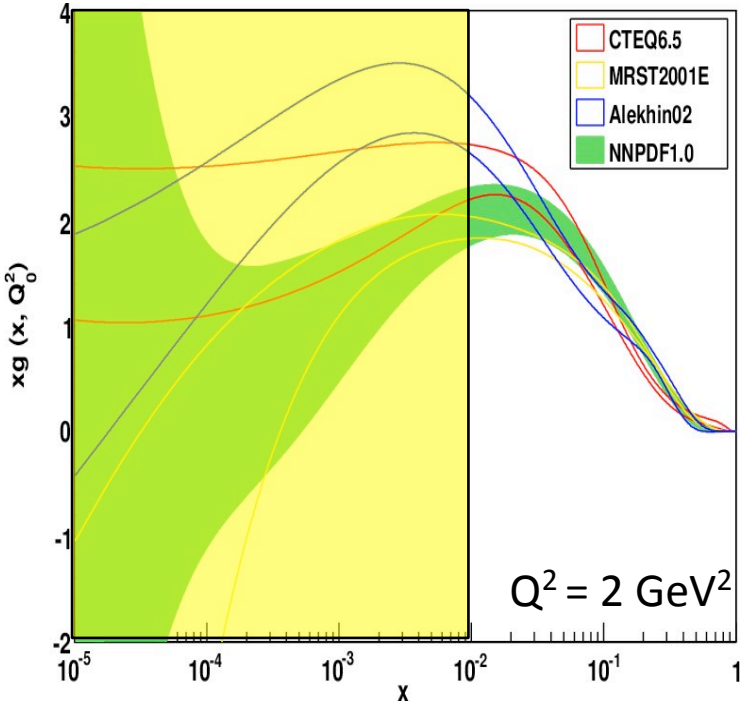
Motivations
Nuclear and proton PDF
Prompt photons
Isolated prompt photons
Tevatron vs NLO p-QCD predictions
Predictions at LHC(y=0)
X-section PDFs
Th. Uncertainties
Predictions at LHC(y=4)

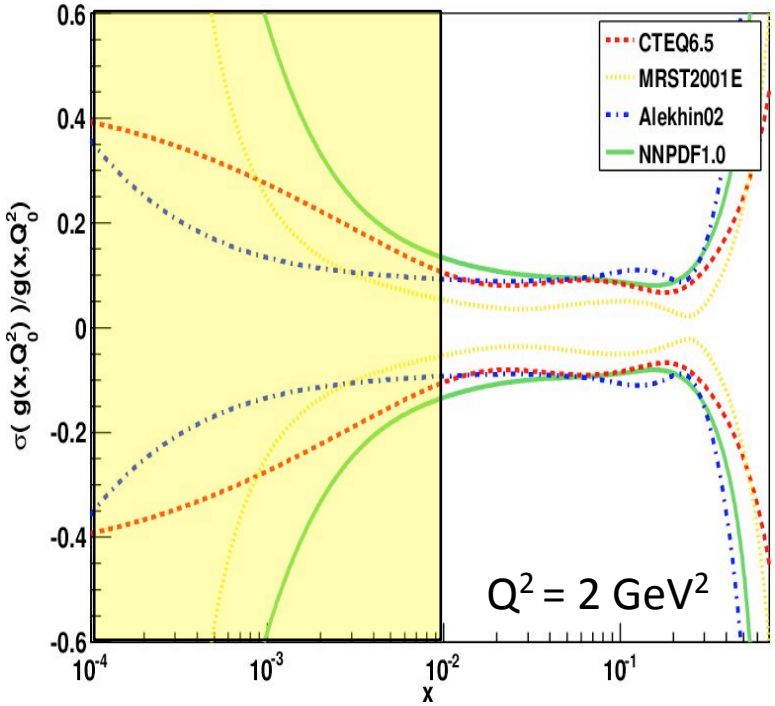
Back-up slides

Proton PDFs (gluon)

- Most of our current knowledge of low-x gluons comes indirectly from e^- proton F_2 "scaling violations": $\frac{\partial F_2(x,Q^2)}{\partial \ln(Q^2)} \approx \frac{10\alpha_s(Q^2)}{27\pi} xg(x,Q^2)$

- Large uncertainties below $x \sim 10^{-2}$ at moderate Q^2 :





Motivations

Nuclear and proton PDF

Prompt photons

Isolated prompt photons

Tevatron vs NLO p-QCD predictions

Predictions at LHC(y=0)

X-section PDFs

Xsection scales

Uncertainties

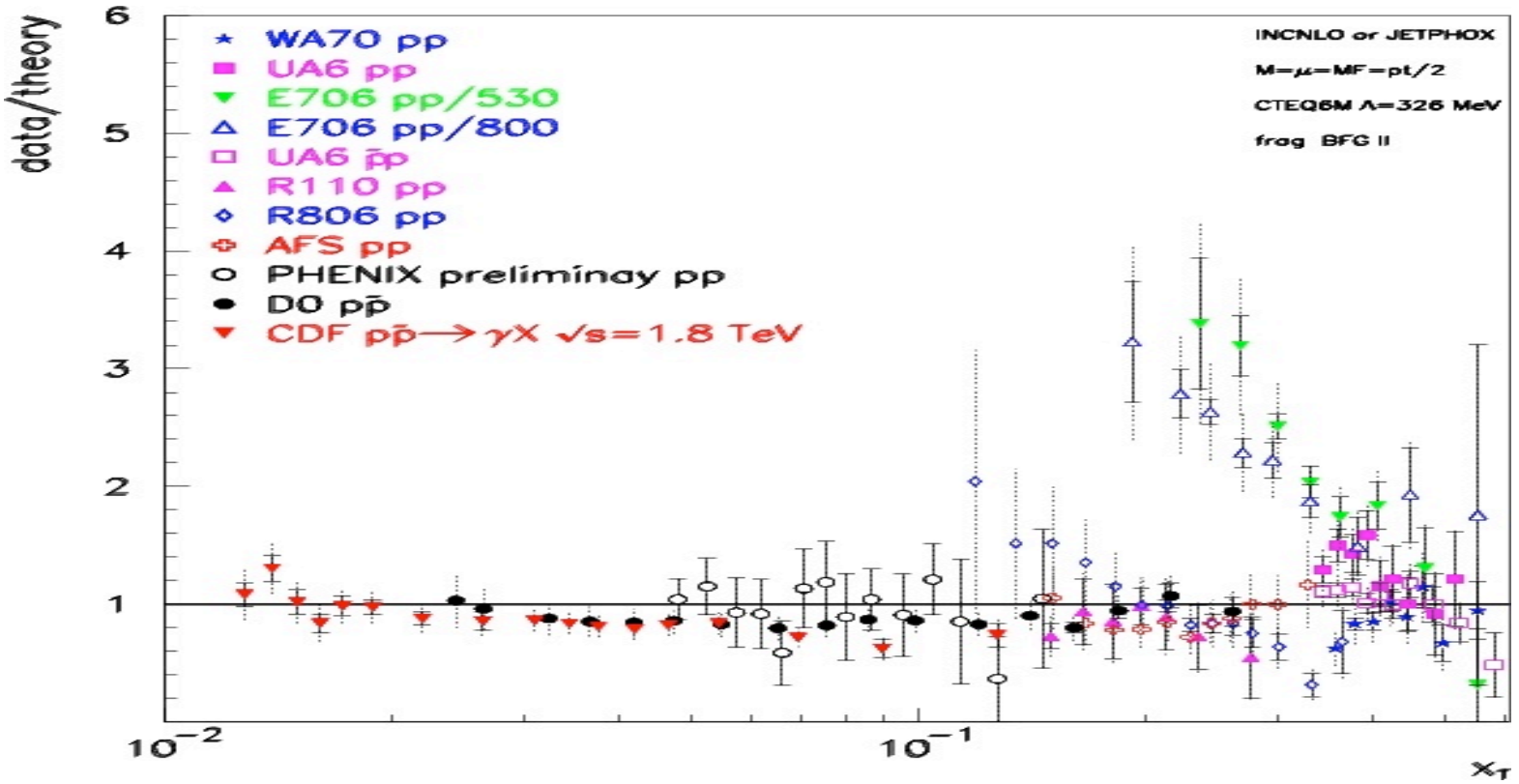
Predictions at LHC(y=4)

X-section PDFs

Xsection scales

Uncertainties

Photon measurements



Direct-g : NLO pQCD calculation

- pQCD NLO calculations with JETPHOX MC

  http://wwwlapp.in2p3.fr/lapth/PHOX_FAMILY/

- pQCD collinear factorization:

$$\frac{d\sigma}{d\vec{p}_T d\eta} = \frac{d\sigma^{(\mathrm{D})}}{d\vec{p}_T d\eta} + \frac{d\sigma^{(\mathrm{F})}}{d\vec{p}_T d\eta}$$

PDFs

Direct: $\frac{d\sigma^{(\mathrm{D})}}{d\vec{p}_T d\eta} = \sum_{i,j=q,\bar{q},g} \int dx_1 dx_2 F_{i/h_1}(x_1, M)\, F_{j/h_2}(x_2, M) \frac{\alpha_s(\mu_R)}{2\pi} \left(\frac{d\hat{\sigma}_{ij}}{d\vec{p}_T d\eta} + \frac{\alpha_s(\mu_R)}{2\pi} K_{ij}^{(\mathrm{D})}(\mu_R, M, M_F) \right)$ ds/dp$_T$dy

PDFs FFs

ds/dp$_T$dy

Frag: $\frac{d\sigma^{(\mathrm{F})}}{d\vec{p}_T d\eta} = \sum_{i,j,k=q,\bar{q},g} \int dx_1 dx_2 \frac{dz}{z^2} F_{i/h_1}(x_1, M)\, F_{j/h_2}(x_2, M)\, D_{\gamma/k}(z, M_F)$

- $\left(\frac{\alpha_s(\mu_R)}{2\pi}\right)^2 \left(\frac{d\hat{\sigma}_{ij}^k}{d\vec{p}_T d\eta} + \frac{\alpha_s(\mu_R)}{2\pi} K_{ij,k}^{(\mathrm{F})}(\mu_R, M, M_F) \right)$

  Interfaced via LHAPDF:

  CTEQ6.6,MSTW08,NNPDF1.2

- Ingredient II: FFs

  BFG parton->g parametrization