QEDevol module in xFitter

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xFitter Workshop, Dubna, 19.02.2016

QEDevol module

- QEDevol module in xFitter performs the evolution of PDFs (q, $\bar{q}$, g, γ) up to NNLO QCD + LO QED in FFNS and VFNS.
- It uses the $n \times n$ evolution toolbox of new version of QCDNUM program (qcdnum-17-01/11).
- QEDevol was cross-checked with partonevolution program of S. Weinzierl and APFEL

QED-modified evolution

QED-modified DGLAP evolution equations for Parton Distribution Functions of quarks $q_i(x, \mu_F^2)$, anti-quarks $q_i(x, \mu_F^2)$, qluon $g(x, \mu_F^2)$ and photon $\gamma(x, \mu_F^2)$ can be written as:

$$\frac{\partial q_i}{\partial \ln \mu^2} = \sum_{j=1}^{n_f} P_{q_i q_j} \otimes q_j + \sum_{j=1}^{n_f} P_{q_i \bar{q}_j} \otimes \bar{q}_j + P_{q_i g} \otimes g + P_{q_i \gamma} \otimes \gamma,$$

$$\frac{\partial \bar{q}_i}{\partial \ln \mu^2} = \sum_{j=1}^{n_f} P_{\bar{q}_i q_j} \otimes q_j + \sum_{j=1}^{n_f} P_{\bar{q}_i \bar{q}_j} \otimes \bar{q}_j + P_{\bar{q}_i g} \otimes g + P_{\bar{q}_i \gamma} \otimes \gamma,$$

$$\frac{\partial g}{\partial \ln \mu^2} = \sum_{j=1}^{n_f} P_{g q_j} \otimes q_j + \sum_{j=1}^{n_f} P_{g \bar{q}_j} \otimes \bar{q}_j + P_{gg} \otimes g,$$

$$\frac{\partial \gamma}{\partial \ln \mu^2} = \sum_{j=1}^{n_f} P_{\gamma q_j} \otimes q_j + \sum_{j=1}^{n_f} P_{\gamma \bar{q}_j} \otimes \bar{q}_j + P_{\gamma\gamma} \otimes \gamma.$$

Splitting kernel expansion including QCD and QED corrections:

$$P = \frac{\alpha_s}{2\pi} P^{(1,0)} + \left(\frac{\alpha_s}{2\pi}\right)^2 P^{(2,0)} + \left(\frac{\alpha_s}{2\pi}\right)^3 P^{(3,0)} + \frac{\alpha}{2\pi} P^{(0,1)} + \ldots$$

QED-modified evolution

For QED-modified DGLAP evolution the following PDF basis is used in `QEDevol`:

$$f_1 = \Delta = u + \bar{u} + c + \bar{c} + t + \bar{t} - d - \bar{d} - s - \bar{s} - b - \bar{b},$$
$$f_2 = \Sigma = u + \bar{u} + c + \bar{c} + t + \bar{t} + d + \bar{d} + s + \bar{s} + b + \bar{b},$$
$$f_3 = g,$$
$$f_4 = \gamma,$$
$$f_5 = \Delta_V = u - \bar{u} + c - \bar{c} + t - \bar{t} - d + \bar{d} - s + \bar{s} - b + \bar{b},$$
$$f_6 = V = u - \bar{u} + c - \bar{c} + t - \bar{t} + d - \bar{d} + s - \bar{s} + b - \bar{b},$$
$$f_7 = \Delta_{ds} = d + \bar{d} - s - \bar{s}, \quad f_{11} = V_{ds} = d - \bar{d} - s + \bar{s},$$
$$f_8 = \Delta_{uc} = u + \bar{u} - c - \bar{c}, \quad f_{12} = V_{uc} = u - \bar{u} - c + \bar{c},$$
$$f_9 = \Delta_{sb} = s + \bar{s} - b - \bar{b}, \quad f_{13} = V_{sb} = s - \bar{s} - b + \bar{b},$$
$$f_{10} = \Delta_{ct} = c + \bar{c} - t - \bar{t}, \quad f_{14} = V_{ct} = c - \bar{c} - t + \bar{t}.$$

QED-modified evolution

Evolution equations in this basis:

$$\frac{\partial}{\partial \ln \mu^2}\begin{pmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \end{pmatrix} = \begin{pmatrix} P_{11} & P_{12} & P_{13} & P_{14} \\ P_{21} & P_{22} & P_{23} & P_{24} \\ P_{31} & P_{32} & P_{33} & P_{34} \\ P_{41} & P_{42} & P_{43} & P_{44} \end{pmatrix} \otimes \begin{pmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \end{pmatrix},$$

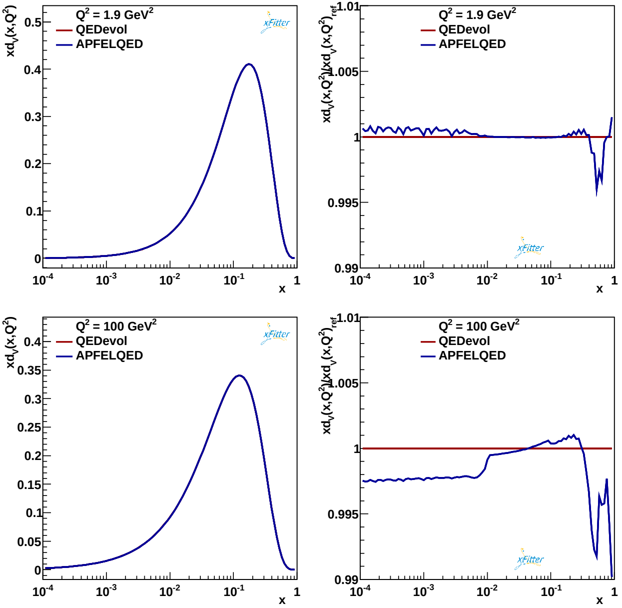
$$\frac{\partial}{\partial \ln \mu^2}\begin{pmatrix} f_5 \\ f_6 \end{pmatrix} = \begin{pmatrix} P_{55} & P_{56} \\ P_{65} & P_{66} \end{pmatrix} \otimes \begin{pmatrix} f_5 \\ f_6 \end{pmatrix},$$

$$\frac{\partial f_i}{\partial \ln \mu^2} = P_{ii} \otimes f_i, \quad i = 7, ..., 14.$$

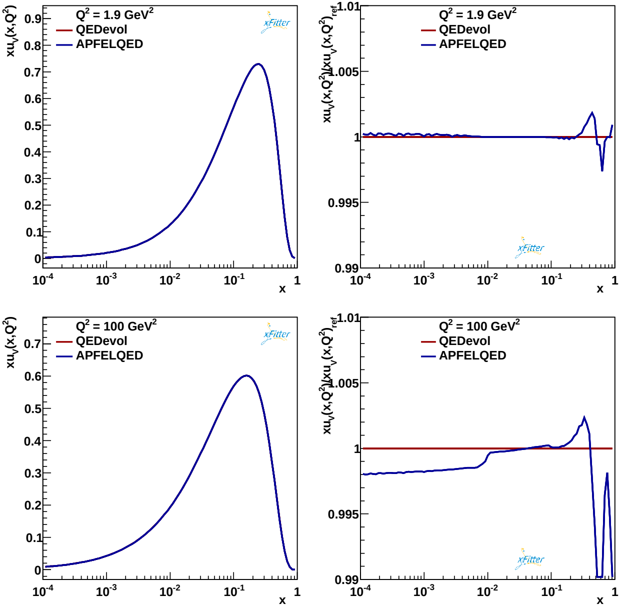
The expressions for splitting kernels P_{ii} at NLO QCD and LO QED are given by

$$\begin{aligned}
P_{11} &= a_s P_{qq}^{(0)} + a_s^2 P_+^{(1)} + \frac{e_u^2+e_d^2}{2} a\tilde{P}_{qq}^{(0)}, \\
P_{12} &= \frac{n_u-n_d}{n_f} a_s^2 (P_{qq}^{(1)} - P_+^{(1)}) + \frac{e_u^2-e_d^2}{2} a\tilde{P}_{qq}^{(0)}, \\
P_{13} &= \frac{n_u-n_d}{n_f} (a_s P_{qg}^{(0)} + a_s^2 P_{qg}^{(1)}), \\
P_{14} &= \frac{n_u e_u^2 - n_d e_d^2}{n_f} aP_{q\gamma}^{(0)}, \\
P_{21} &= \frac{e_u^2-e_d^2}{2} a\tilde{P}_{qq}^{(0)}, \\
P_{22} &= a_s P_{qq}^{(0)} + a_s^2 P_{qq}^{(1)} + \frac{e_u^2+e_d^2}{2} a\tilde{P}_{qq}^{(0)}, \\
&\dots
\end{aligned}
\qquad
\begin{aligned}
P_{33} &= a_s P_{gg}^{(0)} + a_s^2 P_{gg}^{(1)}, \\
P_{34} &= 0, \\
P_{41} &= \frac{e_u^2-e_d^2}{2} aP_{\gamma q}^{(0)}, \\
P_{42} &= \frac{e_u^2+e_d^2}{2} aP_{\gamma q}^{(0)}, \\
P_{43} &= 0, \\
P_{44} &= aP_{\gamma\gamma}^{(0)},
\end{aligned}$$

Comparison of QEDevol and APFEL QED



Comparison of QEDevol and APFEL QED



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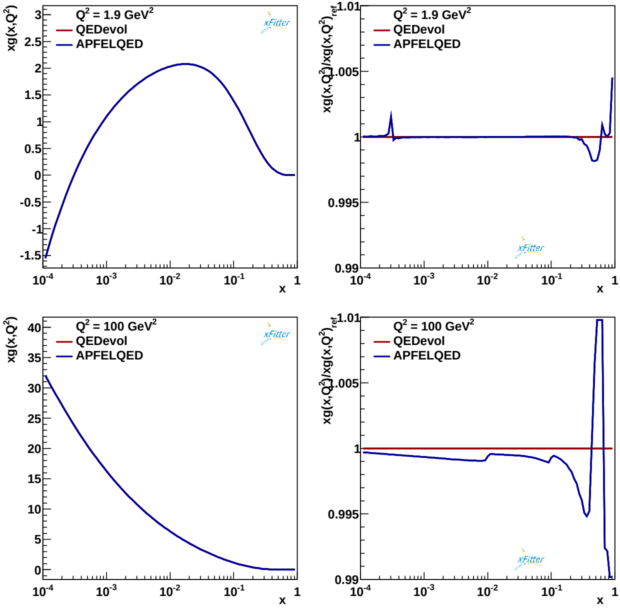

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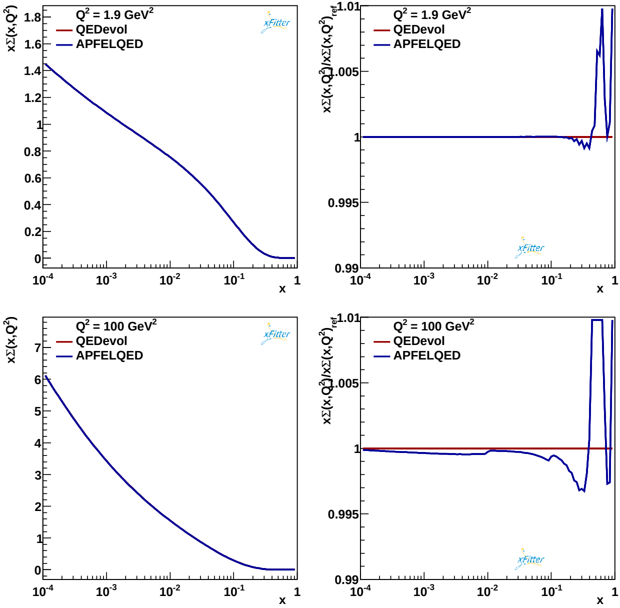

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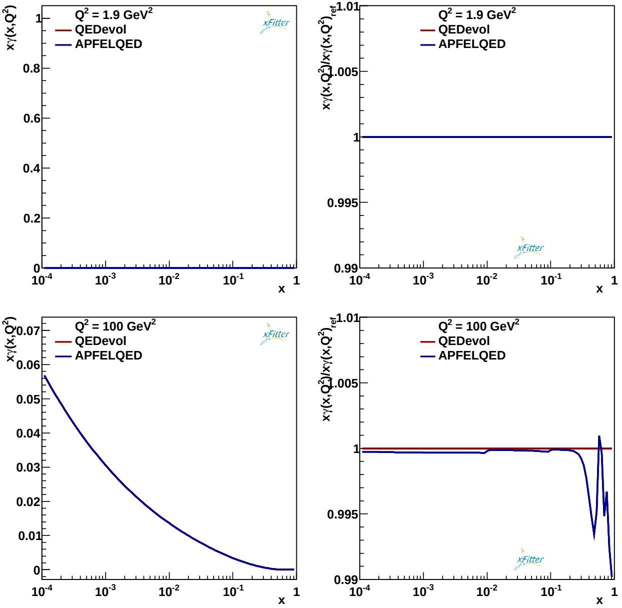

QEDevol in xFitter

- To use QEDevol module change TheoryType flag in steering.txt:

  TheoryType = 'DGLAP_QEDEVOL'
- The QCDNUM version qcdnum-17-01/11 is required: http://www.nikhef.nl/∼h24/qcdnum/QcdnumDownload.html
- Fit with option TheoryType = 'DGLAP_QEDEVOL' is about factor of 1.2 slower than with TheoryType = 'DGLAP_APFEL_QED' and a factor of 2 slower than with TheoryType = 'DGLAP'

Plans:

- To perform fit using APPLGRID interface to SANC for PI Drell-Yan subprocesses
- To include NLO QED corrections