

Fixed Flavour Number Scheme (FFNS) in HERAFitter

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Marseille
13-14.02.2012

- Introduction
- Implementation
- Preformed checks
- Summary

Introduction

Heavy quark treatment in determination of PDFs is important

- different heavy quark schemes in PDF fits exist

- **Fixed Flavour Number Scheme (FFNS)**

light flavours in the proton,

heavy quarks produced only in the final state, massive

$Q^2 \gg m_{\text{HQ}}^2$: can be less precise, NLO coefficients contain terms $\sim \ln(Q/m_{\text{HQ}})$

- **Variable Flavour Number Scheme (VFNS)**

- Zero Mass VFNS: all flavours massless. Breaks at $Q^2 \sim m_{\text{HQ}}^2$

- Generalized Mass VFNS:

combines massive (low scale) and massless (high scale) calculations,

HQ mass used as a parameter at which FFNS turns into VFNS

different implementations provided by PDF groups

Fixed Flavour Scheme: Implementation

Fixed Flavour Schemes in HERAFitter:

- FF from QCDNUM (supports both schemes, VFN and FFN schemes)
- ABKM (openqcdrad1.5, includes pole and running mass definitions) **new**

For tests fit NC data in FFNS

missing NLO coefficients for CC therefore valence params are fixed

Fixed Flavour Scheme: Implementation

FFNS (qcdnum)

- NLO, only electromagnetic exchange contributions

*E. Laenen et al., Nucl. Phys. B392, 162 (1993);
S. Riemersma et al., Phys. Lett. B347, 143 (1995).*

- switch to FF in SETCBT, initialisation/filling of weight tables for HQ SFs
 - scale is defined via relation: $Q^2 = a\mu_F^2 + b$
 - μ_F can be change/varied with respect to μ_R or Q^2 but not to both together
 - HQ contributions added to F2,FL
-
- an increase of nhqstor parameter (qcdnum/) was needed in order to run in FFNS mode

qcdnum: hqstf/inc/hqstf.inc

Fixed Flavour Scheme: Implementation

FFNS can be turned on in steering.txt (similar to RT,...):

```
! --- Scheme for heavy flavors :  
! --- HF_SCHEME = 'ZMVFNS' : ZM-VFNS (massless),  
! --- HF_SCHEME = 'RT' : Thorne-Roberts VFNS (massive)  
...  
! --- HF_SCHEME = 'FF' : Fixed Flavour Number Scheme from qcdnum  
  
HF_SCHEME = 'FF'
```

Scale can be changed/varied in the namelist 'HQScale':

```
&HQScale  
  aq2 = 1.  
  bq2 = -4.  
  MassHQ = 'mc' ! (available: mc, mb)  
&End
```

← default in steering,
sets $\mu_F^2 = Q^2 + 4m_C^2$

TODO: scale definition requires improvement to keep consistency with ABKM scheme

Fixed Flavour Scheme: Checks

Verify SVN version vs older h1fitter (CVS) version (fitting NC data):

SVN

After minimisation 509.181954 518 0.982976744

Dataset 61 110.061188 145

Dataset 62 399.120766 379

NO.	NAME	VALUE	ERROR
Bg	0.11533	0.19949E-01	
Cg	7.4861	0.41146	
Buv	0.66559	fixed	
Cuv	4.6522	fixed	
Cdv	4.2914	fixed	
Adbar	0.17560	0.41951E-02	
Bdbar	-0.15921	0.37394E-02	
CDbar	7.1707	1.2840	
CUbar	2.5112	0.13681	
Euv	9.6938	fixed	
alphas	0.10500	fixed	

CVS

After minimisation 509.18 518 0.983

Dataset 61 110.06 145

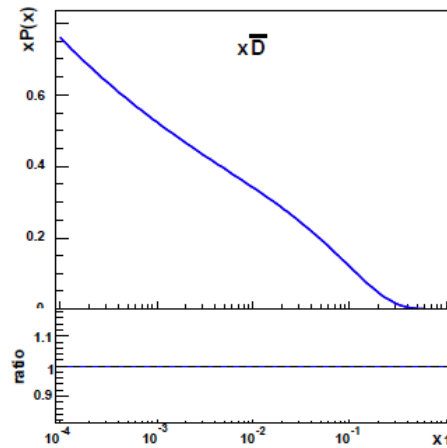
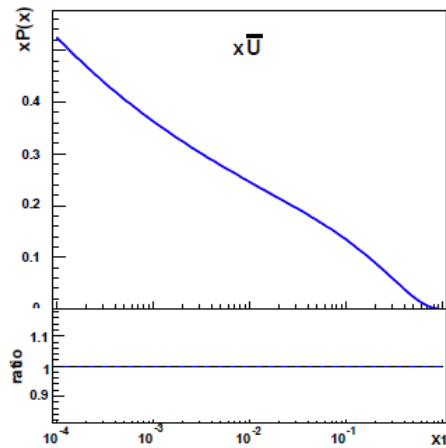
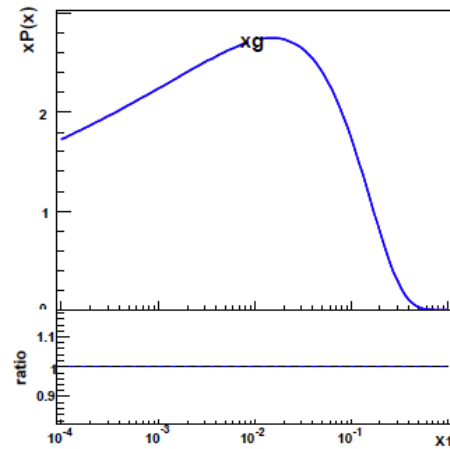
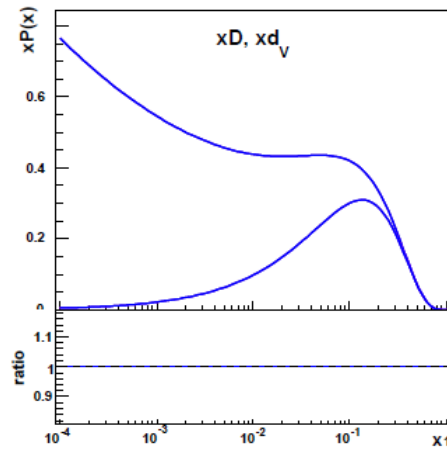
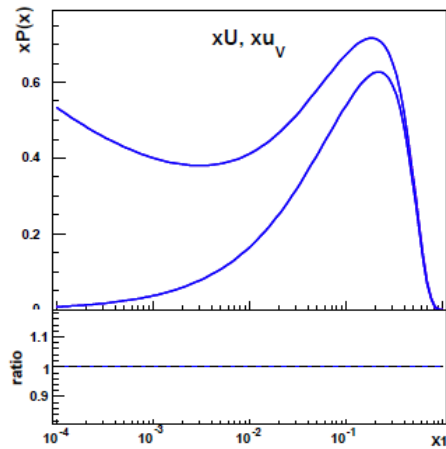
Dataset 62 399.12 379

NO.	NAME	VALUE	ERROR
Bg	0.11533	0.19948E-01	
Cg	7.4861	0.41143	
Buv	0.66559	constant	
Cuv	4.6522	constant	
Cdv	4.2914	constant	
ADbar	0.17560	0.41950E-02	
BDbar	-0.15921	0.37393E-02	
CDbar	7.1706	1.2839	
CUbar	2.5112	0.13681	
Euv	9.6938	constant	
alphas	0.10500	constant	

Two versions give almost identical result (χ^2 and PDFs)
- remaining small differences most likely coming from EW parameters

Fixed Flavour Scheme: Checks

Verify SVN version vs older h1fitter (CVS) version (fitting NC data):



FF in CVS

FF in SVN

$Q^2 = 1.90 \text{ GeV}^2$

Fixed Flavour Scheme: ABKM

in collaboration with Sergey Alekhin

ABKM FF scheme added as another 'add-on' package

- similar to other schemes, wrapper function used to pass relevant parameters (HQ masses, fit order,..)
- missing pieces (xF3) are taken from FF (qcdnum), for light quarks Z contribution taken into account via 'kfactor' (like in RT)
- quite slow, possible kfactors need to be added

```
! --- Scheme for heavy flavors :  
! --- HF_SCHEME = 'ZMVFNS' : ZM-VFNS (massless),  
! --- HF_SCHEME = 'RT' : Thorne-Roberts VFNS (massive)  
....  
! --- HF_SCHEME = 'FF' : Fixed Flavour Number Scheme from qcdnum  
! --- HF_SCHEME = 'ABKM FFNS' : Fixed Flavour Number Scheme from ABKM  
! --- HF_SCHEME = 'ABKM BMSN' : ABKM VFNS in BMSN approach
```

First tests: → verify results versus FF (qcdnum)

ABKM FF vs FF (qcdnum)

ABKM FF → verify results versus FF (qcdnum) fitting NC data

FF (qcdnum)

After minimisation 502.31 518 0.970

Dataset 61 112.99 145

Dataset 62 388.08 379

Correlated Chi2 1.23706089008241

NO.	NAME	VALUE	ERROR
Bg	0.10776	0.20611E-01	
Cg	7.2767	0.44448	
Buv	0.65590	constant	
Cuv	4.6520	constant	
Euv	9.6930	constant	
Cdv	4.3000	constant	
CUbar	2.4741	0.17302	
ADbar	0.17091	0.43527E-02	
BDbar	-0.16191	0.38308E-02	
CDBar	6.5850	1.3108	
alphas	0.10500	constant	

ABKM FF

After minimisation 501.87 518 0.969

Dataset 61 112.75 145

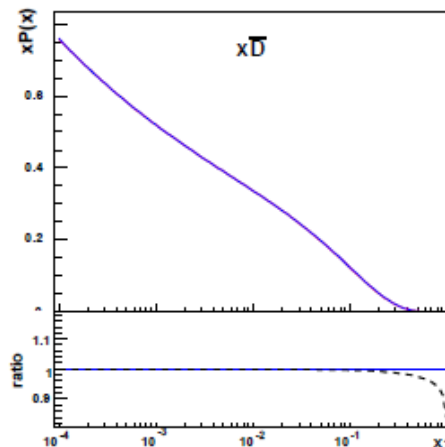
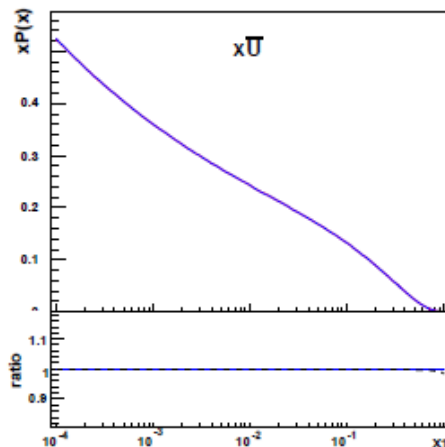
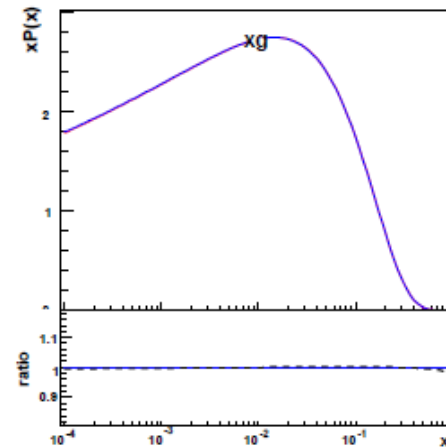
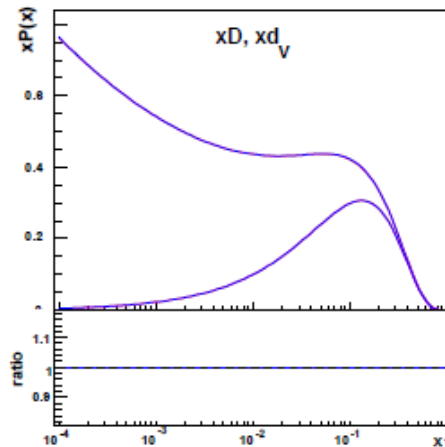
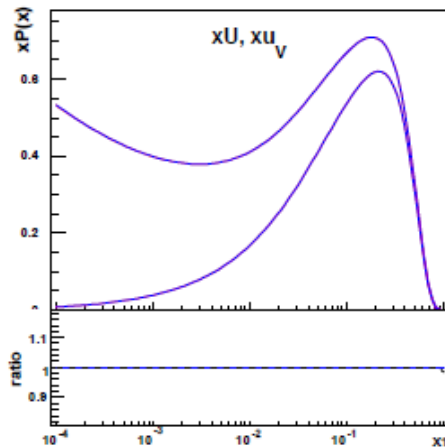
Dataset 62 387.89 379

Correlated Chi2 1.22962720562115

NO	NAME	VALUE	ERROR
Bg	0.10681	0.21130E-01	
Cg	7.2665	0.46212	
Buv	0.65590	constant	
Cuv	4.6520	constant	
Euv	9.6930	constant	
Cdv	4.3000	constant	
CUbar	2.4709	0.17552	
ADbar	0.17080	0.44262E-02	
BDbar	-0.16204	0.38863E-02	
CDBar	6.5476	1.3581	
alphas	0.10500	constant	

ABKM FF vs FF (qcdnum)

ABKM FF → verify results versus FF (qcdnum) fitting NC data

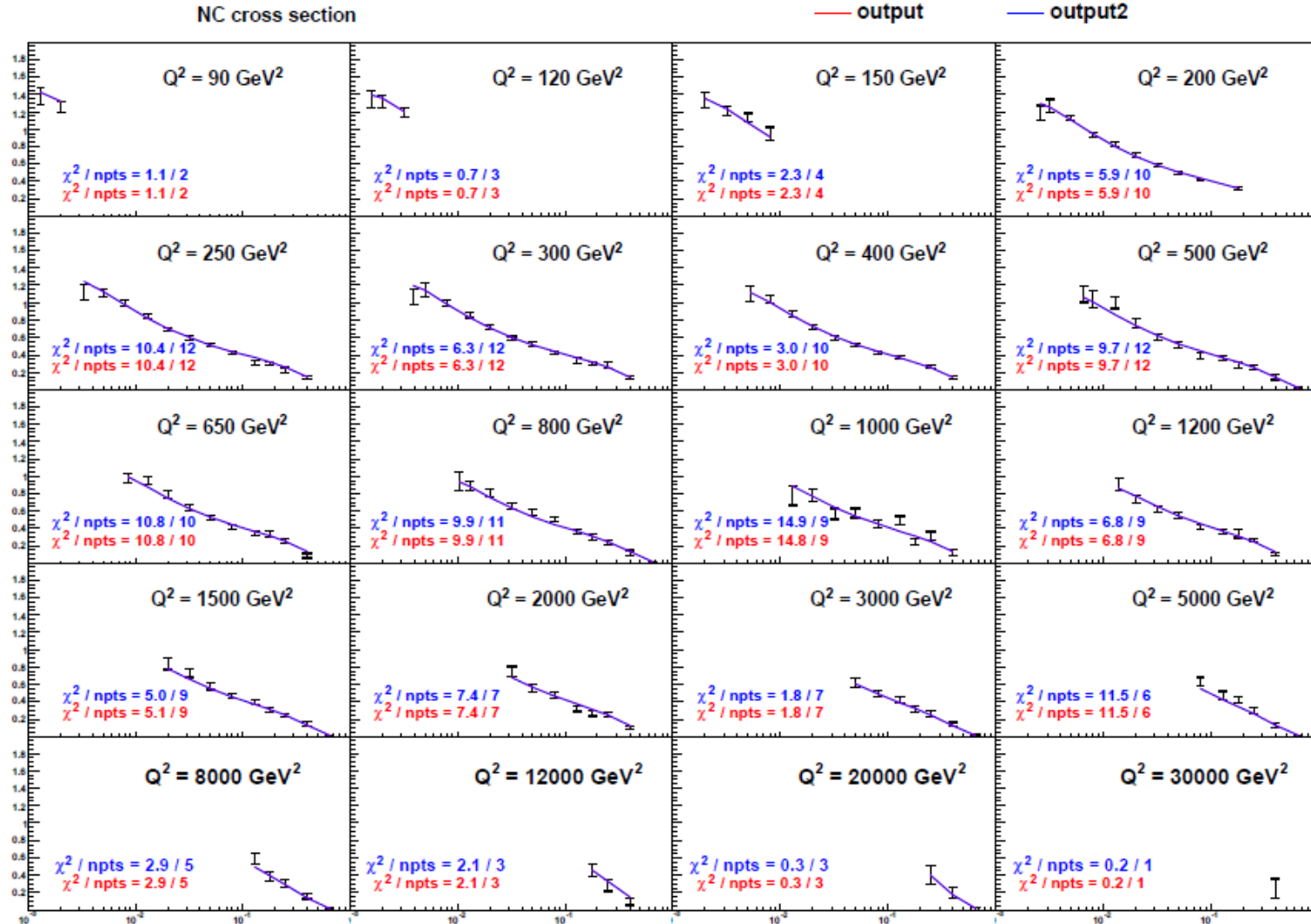


ABKM FF
FF (qcdnum)

$$Q^2 = 1.90 \text{ GeV}^2$$

ABKM FF vs FF (qcdnum)

ABKM FF → verify results versus FF (qcdnum) fitting NC data



ABKM FF (running mass)

ABKM FF: pole and running vs mass definition

ABKM FF

After minimisation 501.87 518 0.969

Dataset 61 112.75 145

Dataset 62 387.89 379

Correlated Chi2 1.22962720562115

NO	NAME	VALUE	ERROR
Bg	0.10681	0.21130E-01	
Cg	7.2665	0.46212	
Buv	0.65590	constant	
Cuv	4.6520	constant	
Euv	9.6930	constant	
Cdv	4.3000	constant	
CUbar	2.4709	0.17552	
ADbar	0.17080	0.44262E-02	
BDbar	-0.16204	0.38863E-02	
CDbar	6.5476	1.3581	
alphas	0.10500	constant	

ABKM (running mass)

After minimisation 501.43 518 0.968

Dataset 61 112.60 145

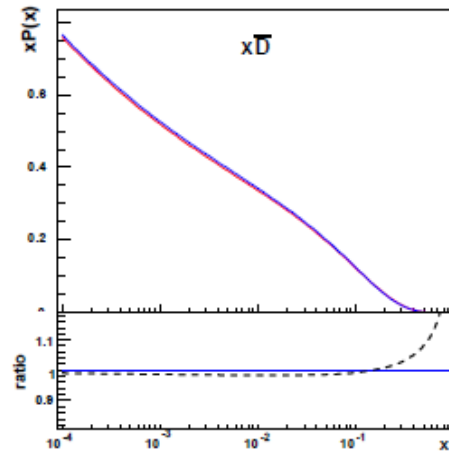
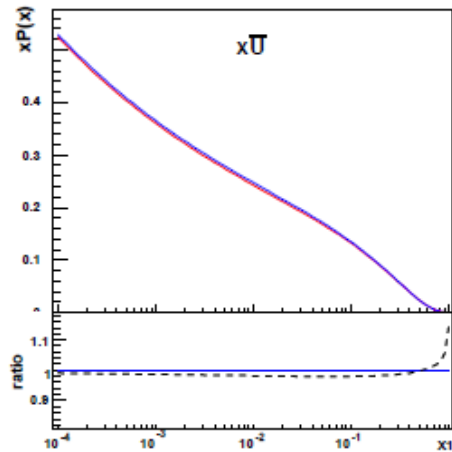
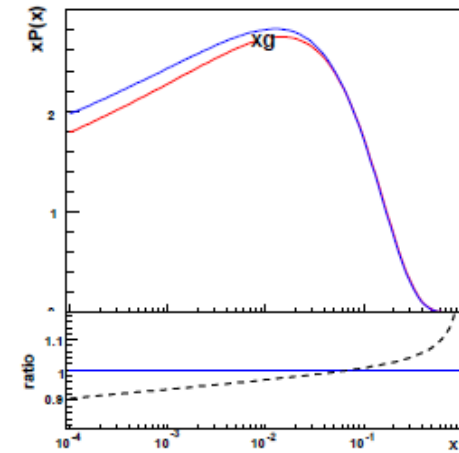
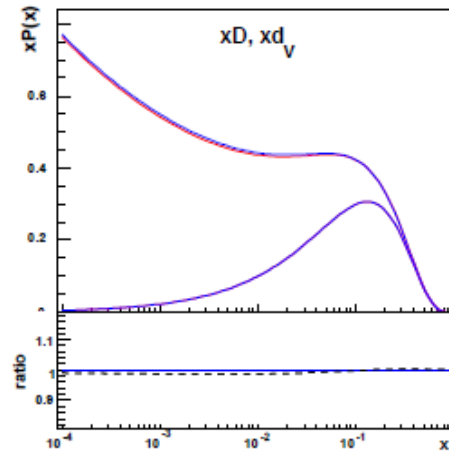
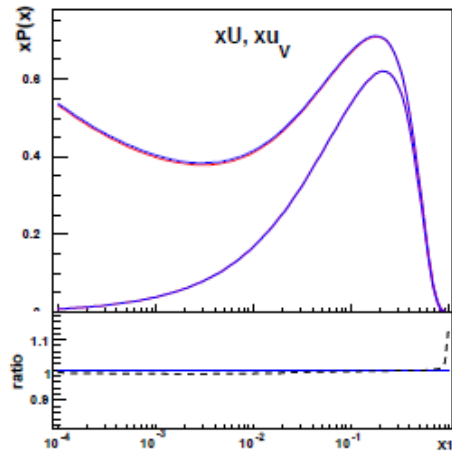
Dataset 62 387.61 379

Correlated Chi2 1.20900899770343

NO.	NAME	VALUE	ERROR
Bg	0.92758E-01	0.20178E-01	
Cg	7.3381	0.44377	
Buv	0.65590	constant	
Cuv	4.6520	constant	
Euv	9.6930	constant	
Cdv	4.3000	constant	
CUbar	2.5052	0.17090	
ADbar	0.17571	0.43654E-02	
BDbar	-0.15992	0.37442E-02	
CDbar	6.6978	1.2867	
Alphas	0.10500	constant	

ABKM FF (running mass)

ABKM FF: pole and running vs mass definition



ABKM FF (run mass)

ABKM FF

$$Q^2 = 1.90 \text{ GeV}^2$$

Summary

FFNS available in HERAFitter (qcdnum and now also ABKM)

- FF ABKM cross checked with FF in qcdnum
- currently FFNSs are implemented with $n_f = 3$
- some tuning to be done (e.g. scale definition)
- ABKM FF scheme includes NNLO approximation for NC and running mass definition

Back-up

- currently FFNS is 'hard coded' with $n_f = 3$

scheme with $n_f = 4$ requires several additional changes (extending evolved quark densities, changing scale, tuning α_s value, calculating contributions of b to SFs), we didn't have it working in CVS version

- question how to correctly deal with b contribution (in current version check on n_f is disabled according to prescription by M. Botje)