Study of parton distributions in π^- within the xFitter framework

Summerstudent report

Novikov Ivan
Supervisor: Alexander Glazov

Moscow Institute for Physics and Technology, Russia

September 5, 2018

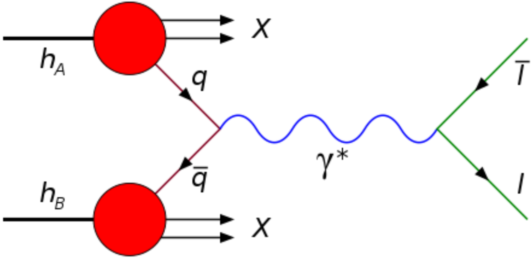


Figure : Drell-Yan process

$$d\sigma(Q^2) = \sum_{\substack{i,j\in \\ \text{flavors}}} \iint_0^1 dx_1 dx_2 \underbrace{f_i^A(x_1, Q^2)}_{\text{PDF}} f_j^B(x_2, Q^2) \underbrace{d\sigma_{ij}(x_1, x_2, Q^2)}_{\substack{\text{calculated} \\ \text{in pQCD}}}$$

- Cannot calculate PDFs $f_i(x) \implies$ fit to data

- An open-source QCD fitting framework
- Various χ^2 definitions and statistical corrections
- Estimation of errors
- Historical role in determination of proton PDFs

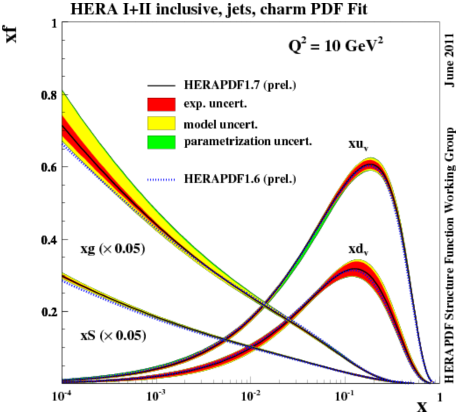


Figure : Example of proton PDF obtained using xFitter

xFitter

- An open-source QCD fitting framework
- Various χ^2 definitions and statistical corrections
- Estimation of errors
- Historical role in determination of proton PDFs
- But no support for particles different from proton ☹

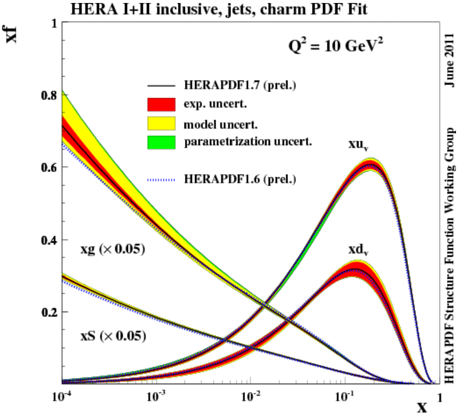


Figure : Example of proton PDF obtained using xFitter

- An open-source QCD fitting framework
- Various χ^2 definitions and statistical corrections
- Estimation of errors
- Historical role in determination of proton PDFs
- ~~But no support for particles different from proton~~ ☺
- Now supports pions too! (My work in experimental branch)

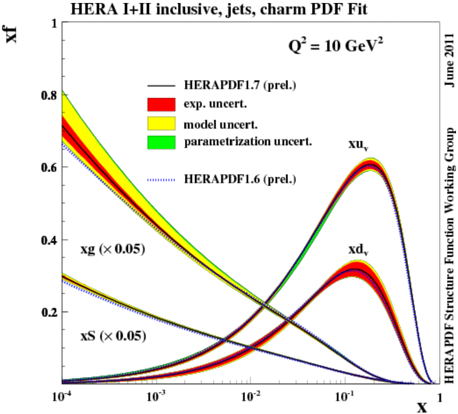


Figure : Example of proton PDF obtained using xFitter

Experiment E615 (Conway et al., Phys. Rev.D39:92–122, 1989)
Drell-Yan scattering of negatively charged pion on a tungsten target:

$$\pi^- + {}_{76}W \to \mu^+\mu^- + X$$

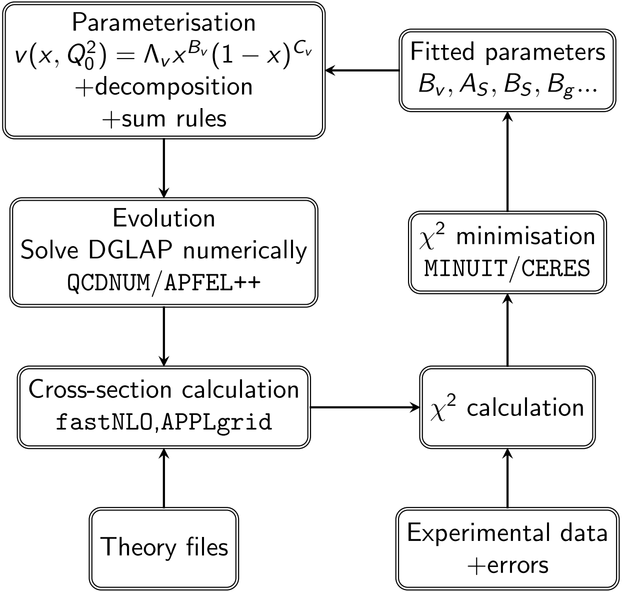
$E_\pi = 252\text{GeV}$
Data provided as $\frac{d\sigma}{dx_F d\sqrt{\tau}}$, where

$$x_F = \frac{2p_L}{\sqrt{s}} \qquad \sqrt{\tau} = \frac{m_{\mu\mu}}{\sqrt{s}},$$

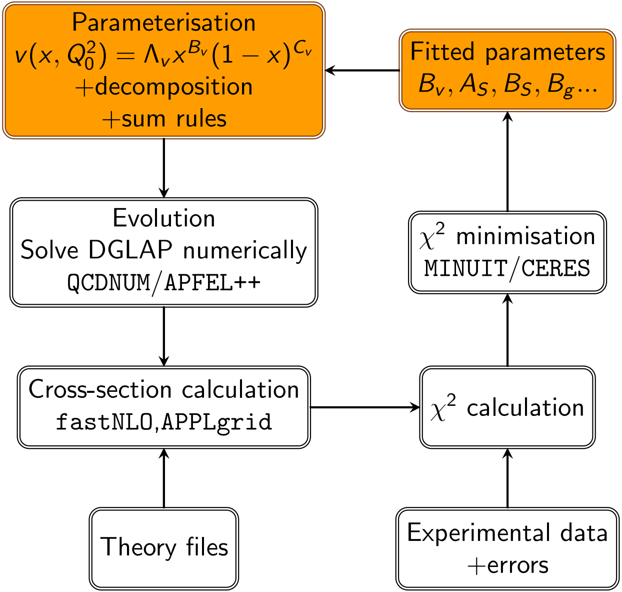
where $m_{\mu\mu}$, p_L are invariant mass and longitudial momentum of the muon pair

TABLE VI. (*Continued*).

$\sqrt{\tau}$ Low	$\sqrt{\tau}$ High	x_F Low	x_F High	$d\sigma/dx_F d\sqrt{\tau}$ (nb/nucleon)
0.300	0.323	0.40	0.50	0.424±0.048
0.300	0.323	0.50	0.60	0.297±0.037
0.300	0.323	0.60	0.70	0.183±0.024
0.300	0.323	0.70	0.80	0.101±0.014
0.300	0.323	0.80	0.90	0.039±0.008
0.323	0.346	−0.20	−0.10	0.388±0.087
0.323	0.346	−0.10	0.00	0.281±0.057
0.323	0.346	0.00	0.10	0.366±0.055


Parameterisation
$v(x, Q_0^2) = \Lambda_v x^{B_v}(1-x)^{C_v}$
+decomposition
+sum rules
Fitted parameters
$B_v, A_S, B_S, B_g \ldots$
Evolution
Solve DGLAP numerically
QCDNUM/APFEL++
χ^2 minimisation
MINUIT/CERES
Cross-section calculation
fastNLO,APPLgrid
χ^2 calculation
Theory files
Experimental data
+errors

Fitting cycle



Assume $SU(3)$-symmetric sea at starting scale $Q_0^2 = 1.9\text{GeV}^2$:

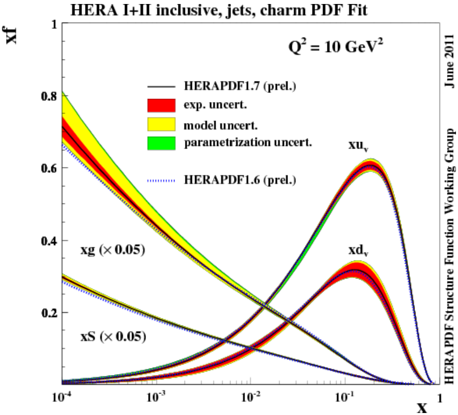
$$d = \bar{u} \qquad\qquad u = \bar{d} = s = \bar{s}$$

Parameterise distributions

$$v := \frac{d - \bar{d} - u + \bar{u}}{2} := \Lambda_1 x^{B_v}(1-x)^{C_v}$$

$$S := \frac{u + \bar{d}}{2} := A_S x^{B_S}(1-x)^{C_S}$$

$$g := g := \Lambda_2 x^{B_g}(1-x)^{C_g}$$



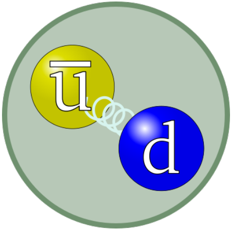
$$v := \Lambda_1 x^{B_v}(1-x)^{C_v}$$
$$S := A_S x^{B_S}(1-x)^{C_S}$$
$$g := \Lambda_2 x^{B_g}(1-x)^{C_g}$$

Here Λ_1 and Λ_2 are not free, but constrained by sum rules:

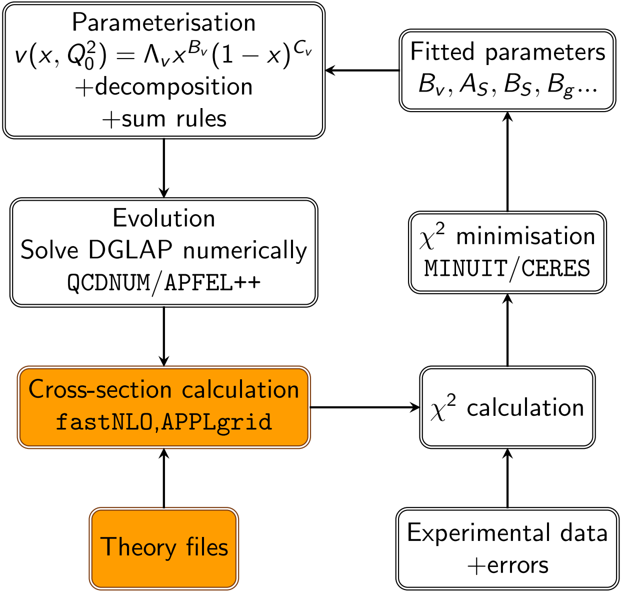
$$\int_0^1 (u-\bar{u})\,dx = -1 \qquad \int_0^1 \left(d-\bar{d}\right)\,dx = 1$$
$$\int_0^1 x(u+\bar{u}+d+\bar{d}+s+\bar{s}+g)dx = 1$$

or, in terms of v, S, g:

$$\int_0^1 v dx = 1 \qquad \int_0^1 x(2v+6S+g)dx = 1$$



π^-

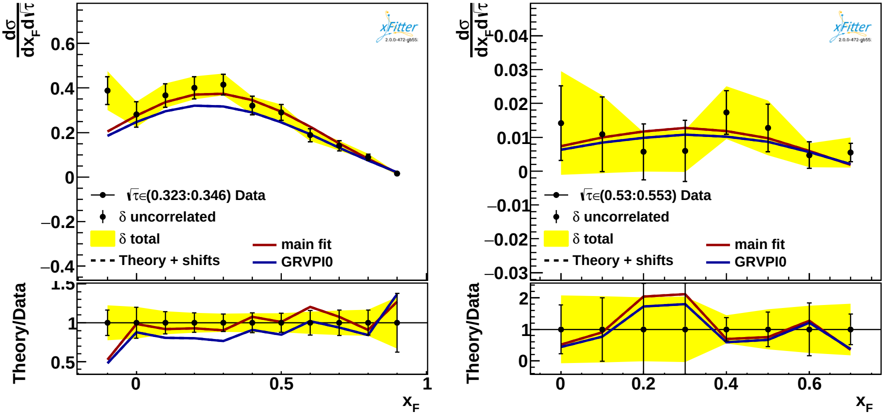

Parameterisation
$v(x, Q_0^2) = \Lambda_v x^{B_v}(1-x)^{C_v}$
+decomposition
+sum rules
Fitted parameters
$B_v, A_S, B_S, B_g \dots$
Evolution
Solve DGLAP numerically
QCDNUM/APFEL++
χ^2 minimisation
MINUIT/CERES
Cross-section calculation
fastNLO,APPLgrid
χ^2 calculation
Theory files
Experimental data
+errors

Full calculation of NLO cross-sections at each iteration is too slow
We used `APPLgrid` library to calculate cross section:

$$\iint_0^1 dx_1 dx_2 f^{\pi}(x_1) f^{\text{target}}(x_2) d\sigma(x1, x2) \rightsquigarrow \sum_{i,j=1}^{N} f^{\pi}(x_i) f^{\text{target}}(x_j) W_{ij}$$

- Pion PDF f^{π} varied during fit
- Tungsten target PDF f^{target} — used `LHAPDF` set `nCTEQ15FullNuc_184_74` (Kovarik et.al., Phys. Rev. D93, 2016)
- W_{ij} generated once by running 1000 instances of `MCFM` on `BIRD`

Fit results



The results are compared to the only pion PDF set available in LHAPDF library GRVPI0 (Glück et.al.,Z.Phys.C53, 1992)

$$\frac{\chi^2}{N_{DoF}} = \frac{209.10}{138} = 1.53$$

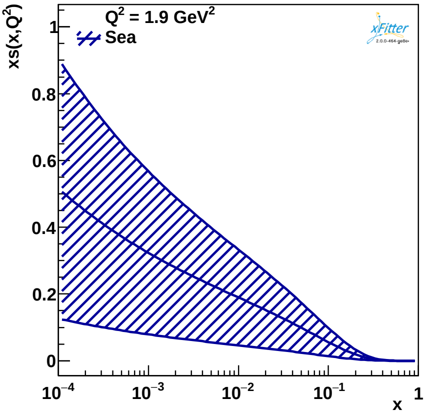


Figure : Sea distribution is poorly constrained

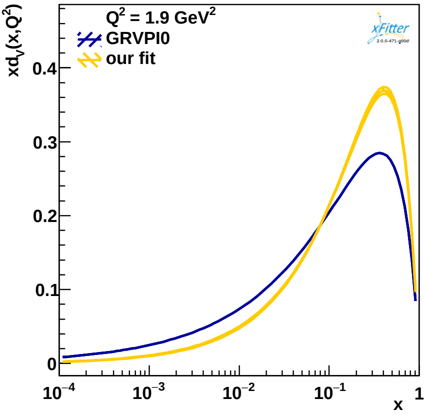


Figure : Obtained valence distribution compared to `GRVPI0`

$$v = \Lambda_1 x^{B_v}(1-x)^{C_v}$$

$$B_v = 0.6817 \pm 0.013$$

$$C_v = 0.9794 \pm 0.023$$

Thank you for your attention!

Backup slides

$f(x, Q^2)$ depend on scale Q^2

Dokshitzer-Gribov-Lipatov-Altarelli-Parisi Equations

$$\frac{\partial f_i(x, Q^2)}{\partial \ln(Q^2)} = \sum_{j \in \{q, \bar{q}, g\}} \int_x^1 \frac{dz}{z} P_{ij}\left(\frac{x}{z}, Q^2\right) f_j(z, Q^2)$$

- Evolve $f(x, Q_0^2) \to f(x, Q_1^2)$
- Splitting functions P_{ij} are derived in perturbative QCD