Generalised VDM and F_2 data at low Q^2

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Problem:

DIS formalism and parton pdf's applied at very low Q^2

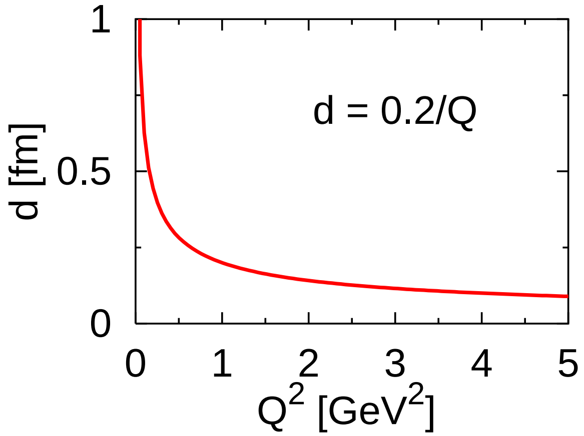
$$\frac{d\sigma}{dx\,dQ^2} \sim F_2(x,Q^2) \sim xq(x,Q^2)$$

$$\Downarrow$$

need quark densities, but no or negative gluon density to avoid too much DGLAP evolution

Solution:

Low Q^2 does not resolve partons!



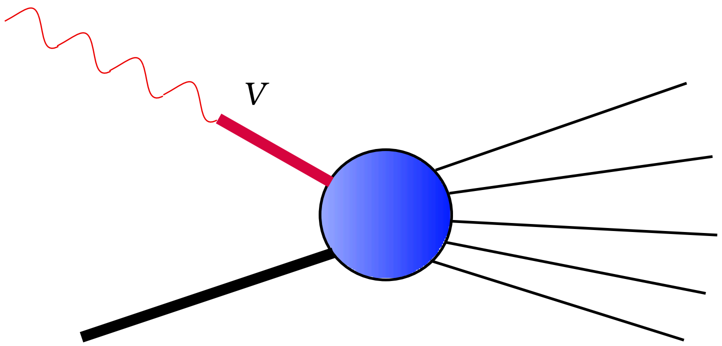
Generalised vector meson dominance model accounts for cross-section at $Q^2 \lesssim 1$ GeV^2

$\hookrightarrow$ parton pdf's work well for $Q^2 \gtrsim 1$ GeV^2

Generalised Vector Meson Dominance Model

Following Sakurai-Schildknecht and others

Quantum fluctuations $|\gamma\rangle = C_0|\gamma_0\rangle + \sum_V \frac{e}{f_V}|V\rangle$
i.e. photon $\rightarrow$ vector mesons $V = \rho^0, \omega, \phi \ldots$
followed by $Vp \rightarrow X$ with soft hadronic
transverse & longitudinal cross-sections
including continuum $m_V > m_0$ contribution



$$\sigma_T^{\mathrm{GVDM}} = \left\{ \sum_V \frac{4\pi\alpha}{f_V^2} \left(\frac{m_V^2}{m_V^2+Q^2} \right)^2 + r_C \frac{m_0^2}{m_0^2+Q^2} \right\} \sigma_{Vp}$$

$$\sigma_L^{\mathrm{GVDM}} = \left\{ \sum_V \frac{4\pi\alpha}{f_V^2} \left(\frac{m_V^2}{m_V^2+Q^2} \right)^2 \frac{Q^2}{m_V^2} \xi_V + r_C \left(\frac{m_0^2}{Q^2} \ln \left(1 + \frac{Q^2}{m_0^2} \right) - \frac{r_C m_0^2}{m_0^2+Q^2} \right) \xi_C \right\} \sigma_{Vp}$$

with expected suppression $\xi_{V,C} = \sigma_L/\sigma_T \approx 0.6$ of longitudinal cross-section

Use normal total hadronic cross-section $\sigma_{Vp} = A_V s^{\epsilon} + B_V s^{-\eta}$ with $\epsilon \approx 0.08$

GVDM in ep scattering at low-Q^2

$F_2(x,Q^2) = \frac{(1-x)Q^2}{4\pi^2\alpha}(\sigma_T+\sigma_L)$ and $s_{\gamma p} = Q^2\,\frac{1-x}{x} + m_p^2 \approx Q^2/x$ at small-x

Inserting $\sigma_{T,L}^{\mathrm{GVDM}}$ (neglecting small ξ_C-term) gives

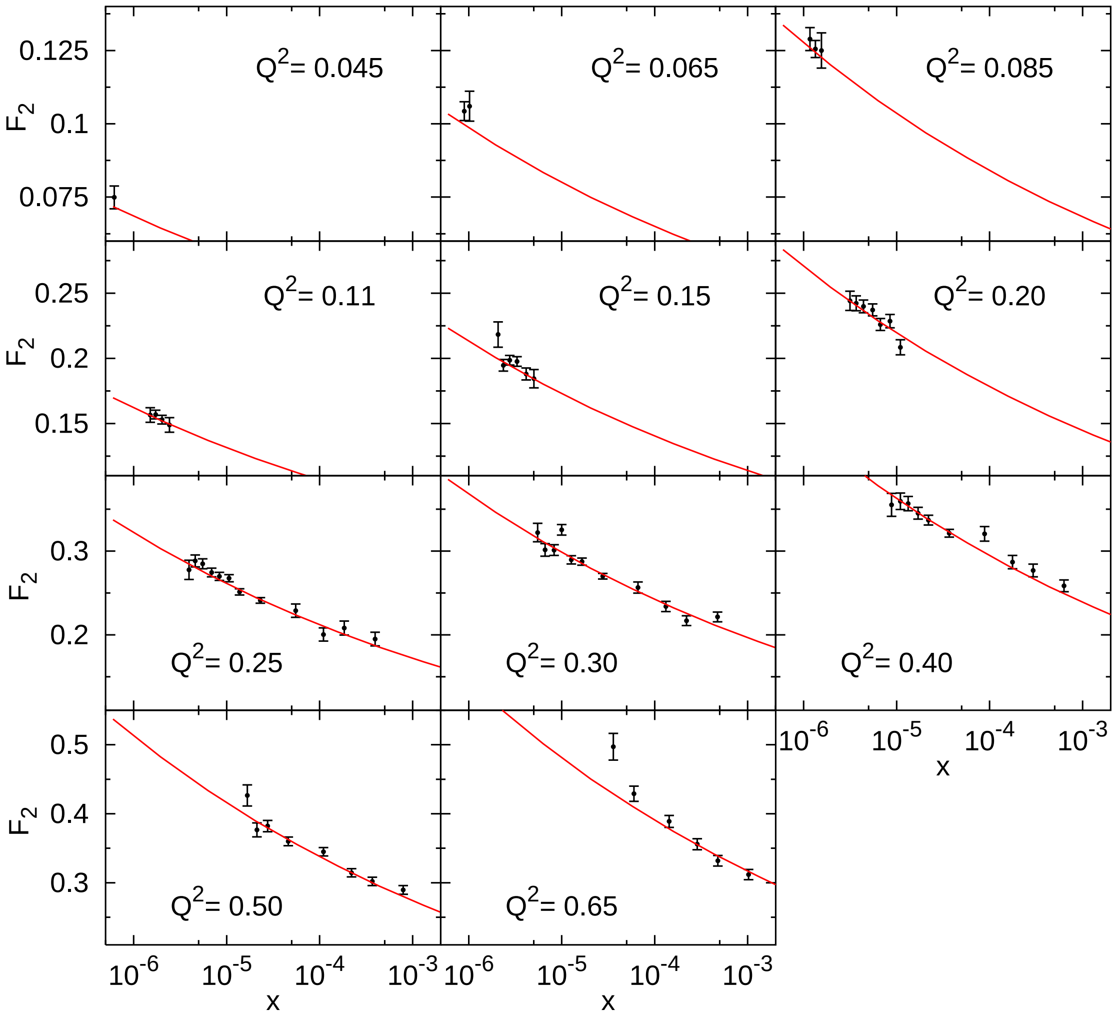
$$F_2^{\mathrm{GVDM}}(x,Q^2) = \frac{(1-x)Q^2}{4\pi^2\alpha}\left\{\sum_V r_V \left(\frac{m_V^2}{Q^2+m_V^2}\right)^2 \left(1+\xi\frac{Q^2}{m_V^2}\right) + r_C\frac{m_0^2}{Q^2+m_0^2}\right\} A\left(\frac{Q^2}{x}\right)^{\epsilon}$$

More complex Q^2-dependence from σ_L and continuum than simple VDM

Essential $x^{-\epsilon}$ from $\sigma_{Vp}(s) \sim s^{\epsilon} \sim \left(\frac{Q^2}{x}\right)^{\epsilon}$ neglecting Reggeon at small-x

Parameters: $r_V = \frac{4\pi\alpha}{f_V^2}\frac{A_V}{A}$, $r_C = 1-\sum_V r_V$; $m_0 = 0.9$ GeV

$r_{V=\rho,\omega,\phi,C} = 0.67, 0.062, 0.059, 0.21$ $\longrightarrow$ to be fitted ϵ, A, $\xi = \xi_{V=\rho,\omega,\phi}$



HERA F_2 at low Q^2

ZEUS 1997 data

GVDM model fits well

$$\chi^2 = 89/(70-3) = 1.3$$

with parameter values

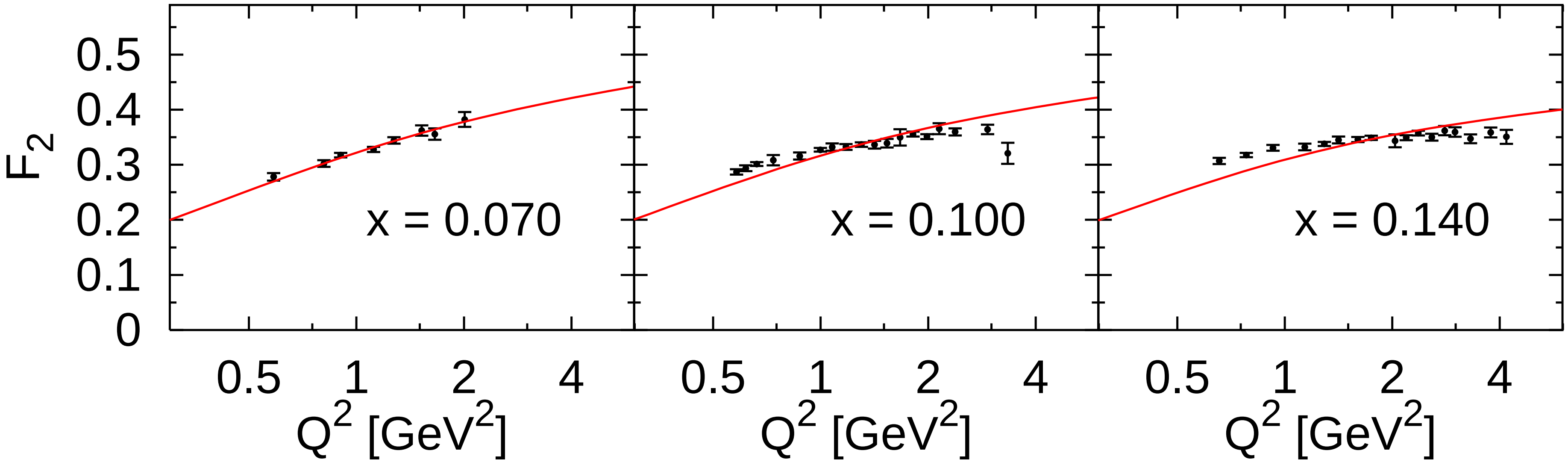
$$\epsilon = 0.09$$
$$A = 71\,\mu\text{b}$$
$$\xi = 0.6$$

as expected

SLAC F_2 at intermediate x

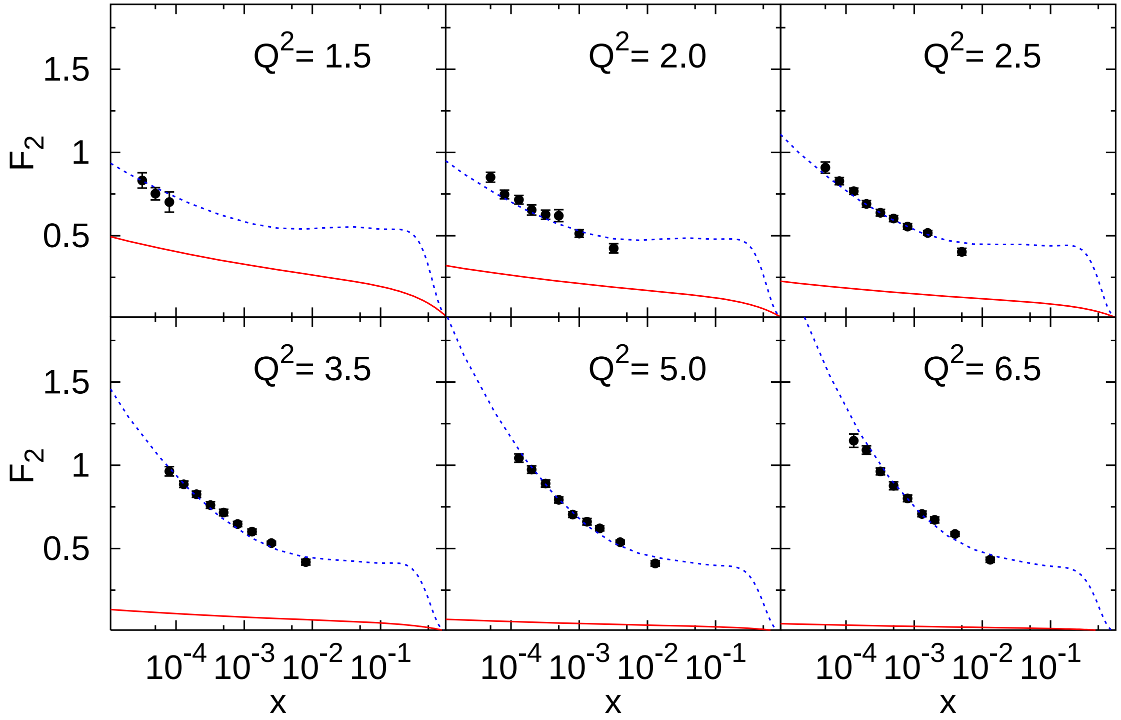
x not small $\rightarrow$ need full $\sigma_{Vp} = A_V s^{\epsilon} + B_V s^{-\eta}$ with Reggeon term

Then GVDM model fitted to HERA describes also the SLAC F_2 data



HERA F_2 at intermediate Q^2

In DIS-region: GVDM needs scale-down (form factor) with Q^2



GVDM $\times \left(\frac{Q_0^2}{Q^2}\right)^a$ with $a = 1.8$

for $Q^2 > Q_0^2 = 1.26$ (fitted)

$\rightarrow$ GVDM negligible for $Q^2 \gtrsim 3$

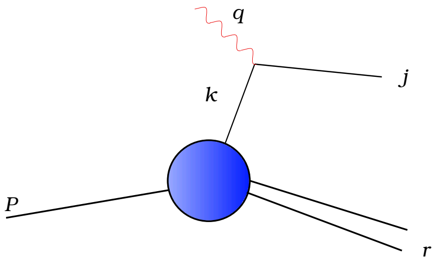
Adding parton densities,
here Alwall-Edin-Ingelman model,
gives good description of data
without negative gluon density

Model for x-shape of parton densities at Q_0^2

Valence quarks and gluons:

Gaussian momentum fluctuations

$\sigma \sim \Delta p \sim \hbar/\Delta x \sim \hbar/1 \text{ fm} \sim 200 MeV$



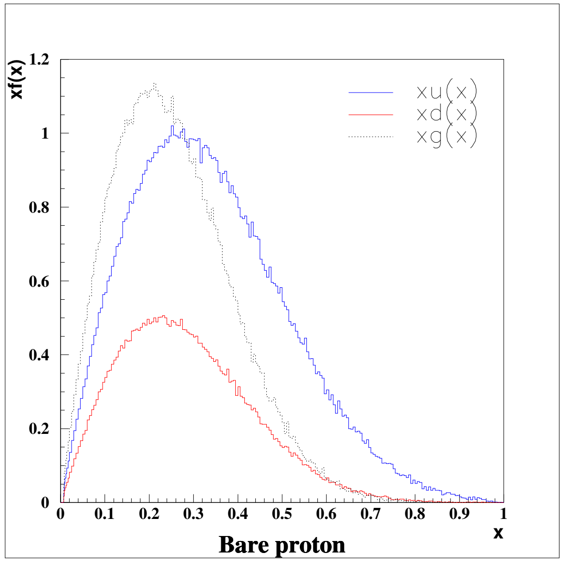
kinematic constraints

$0 < j^2 < W^2,\ r^2 > 0$

$x = \frac{k_+}{P_+}$

$\Downarrow$

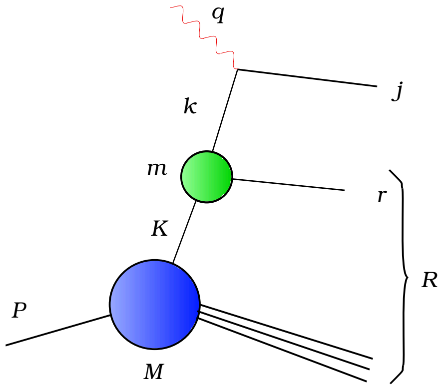
Valence distributions at $Q_0 = 0.85$



Sea quarks and gluons:

similar scattering on partons in hadronic fluctuations

$|p\rangle = \alpha_0 |p_0\rangle + \alpha_1 |p_0 \pi^0\rangle + \alpha_2 |n\pi^+\rangle + \ldots$



$\Downarrow$

$u_v(x) \neq d_v(x)$

$\bar{u}(x) \neq \bar{d}(x)$

$\approx$ as in data

Natural to consider hadronic fluctuations also of initial photon

$\Rightarrow$ GVDM

Conclusions

Full GVDM model . . .

- σ_L contribution
- continuum contribution
- few fitted parameters

. . . reproduces . . .

- HERA F_2 at low-x, low-Q^2 having $F_2 \sim x^{-\epsilon}$ with $\epsilon = 0.09$
- SLAC F_2 at intermediate x (~ 0.1)

In DIS-region $Q^2 \gtrsim 1$ GeV^2

- GVDM damped by $\left(\frac{Q_0^2}{Q^2}\right)^a$ form factor $\rightarrow$ negligible for $Q^2 \gtrsim 3$
- $F_2(x, Q^2)$ dominated by normal parton densities, negative gluon density avoided
- Our model for x-shape of pdf's at $Q_0^2 \sim 1$ GeV^2 $\otimes$ DGLAP fits F_2 and gives $u_v(x) \neq d_v(x)$, $\bar{u}(x) \neq \bar{d}(x)$ as in data, but that's another story . . .

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