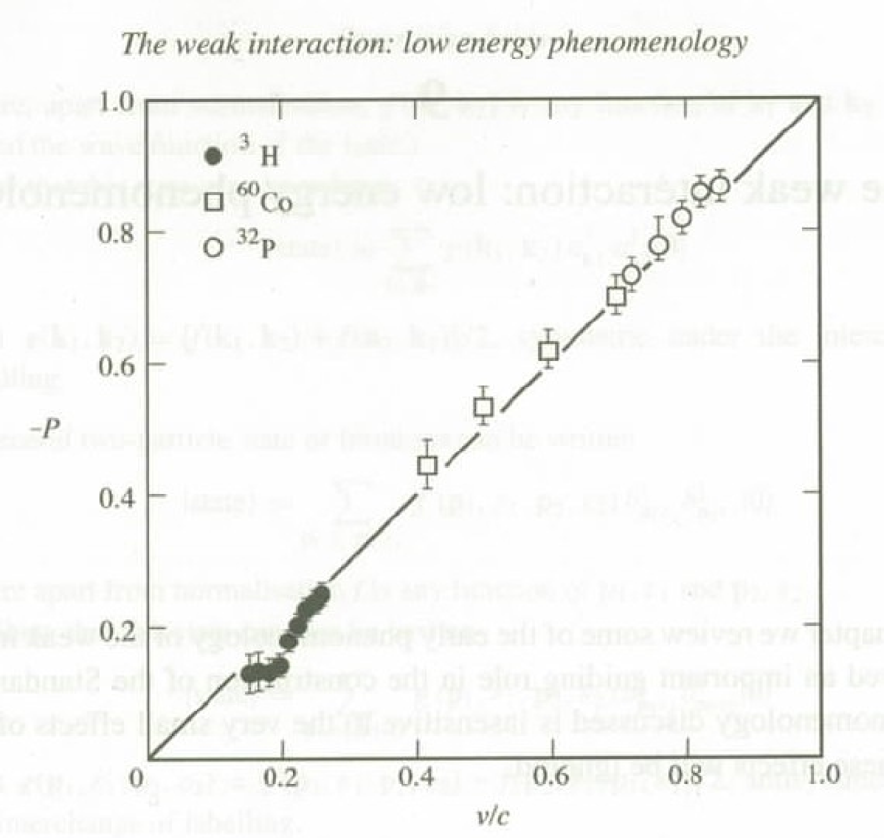
Weak Decays and Interactions

- parity violation in weak decays
- charged currents
- muon decay
- lepton scattering experiments

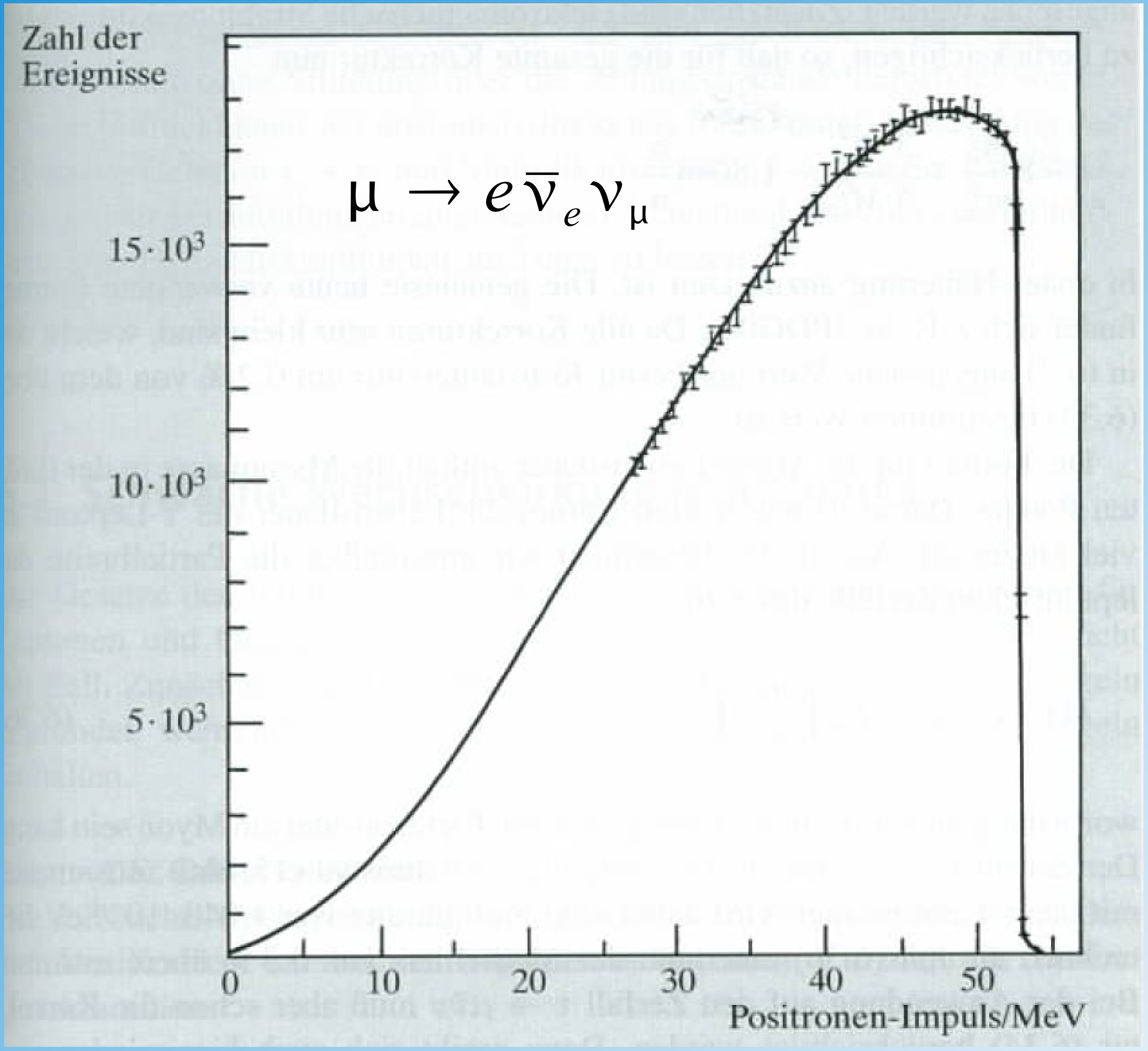
Polarisation in Beta Decays

polarisation: $$P = \frac{N(+\frac{1}{2}) - N(-\frac{1}{2})}{N(+\frac{1}{2}) + N(-\frac{1}{2})}$$



only left-handed particles!

Michel-Spectrum



Spinors fermions / anti-fermions

(spin polarisation along z-axis)

fermions:

$$u_{1(R)} = \sqrt{E+m} \begin{pmatrix} 1 \\ 0 \\ \frac{p_z}{E+m} \\ \frac{p_x+ip_y}{E+m} \end{pmatrix} \qquad u_{2(L)} = \sqrt{E+m} \begin{pmatrix} 0 \\ 1 \\ \frac{p_x-ip_y}{E+m} \\ \frac{-p_z}{E+m} \end{pmatrix}$$

anti-fermions:

$$v_{1(R)} = \sqrt{E+m} \begin{pmatrix} \frac{p_x-ip_y}{E+m} \\ \frac{-p_z}{E+m} \\ 0 \\ 1 \end{pmatrix} \qquad v_{2,(L)} = \sqrt{E+m} \begin{pmatrix} \frac{p_z}{E+m} \\ \frac{p_x+ip_y}{E+m} \\ 1 \\ 0 \end{pmatrix}$$

Chirality Operator

limit m → 0

$$u_R \sim v_L \sim \begin{pmatrix} 1 \\ 0 \\ 1 \\ 0 \end{pmatrix} \qquad u_L \sim v_R \sim \begin{pmatrix} 0 \\ 1 \\ 0 \\ 1 \end{pmatrix}$$

operator:

$$\gamma^5 = i\gamma^0\gamma^1\gamma^2\gamma^3 = \begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 0 & \underline{1} \\ \underline{1} & 0 \end{pmatrix}$$

right chirality	left chirality
$\gamma_5 u_R = u_R$	$\gamma_5 u_L = -u_L$
$\gamma_5 v_L = v_L$	$\gamma_5 v_R = -v_R$

eigenvalues ± 1

left-handed (chiral) particles: -1

right-handed (chiral) particles: +1

note: a right-handed chiral anti-particle has a left-handed helicity

Projection Operator

definition: $\Pi^{\pm} = \frac{1 + \gamma_5}{2}$

fermions		anti-fermions	
$\Pi^{+} u_R = u_R$	$\Pi^{+} u_L = 0$	$\Pi^{+} v_L = v_L$	$\Pi^{+} v_R = 0$
$\Pi^{-} u_L = u_L$	$\Pi^{-} u_R = 0$	$\Pi^{-} v_R = v_R$	$\Pi^{-} v_L = 0$

projection:

$\Pi^{+} \psi = R$ (right-handed (chiral) state)

$\Pi^{-} \psi = L$ (left-handed (chiral) state)

reformulate Dirac Equation:

$$i\gamma^{\mu}\partial_{\mu} R = m\, L \qquad i\gamma^{\mu}\partial_{\mu} L = m\, R$$

note: massive fermions must have left-handed and right handed components

Vector and Axial Currents

Vector Current:

$j_V^\mu = \bar{\Psi}\gamma^\mu\psi \quad (R\gamma^\mu R,\ \ L\gamma^\mu L)$ in QED: $\partial_\mu j_V^\mu = 0$ (conservation of currents)

Axial-vector Current:

$j_A^\mu = \bar{\Psi}\gamma^\mu\gamma^5\psi$ note: $\gamma^\mu\gamma^5 = -\gamma^5\gamma^\mu$

Left (right)-handed Current:

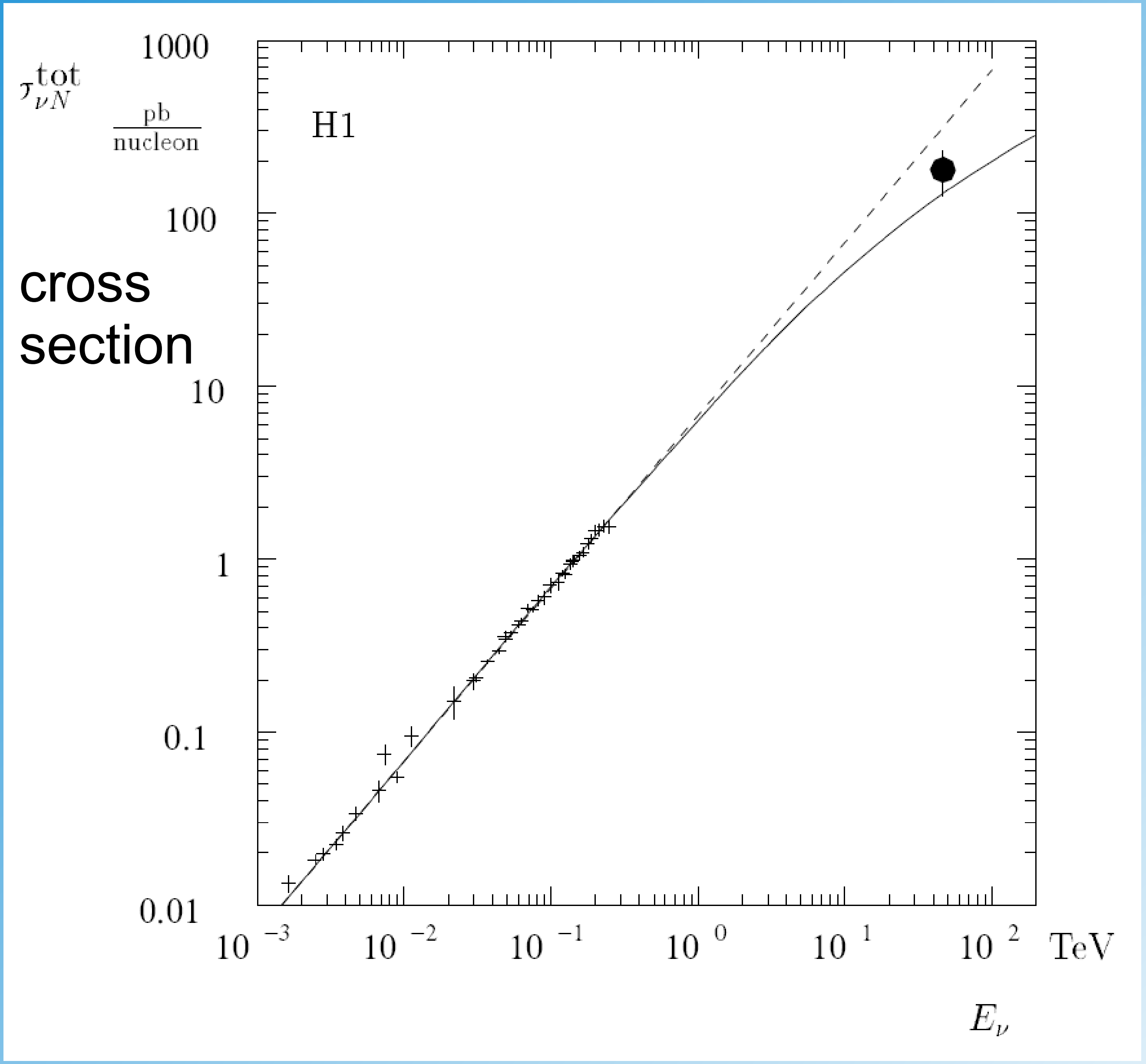
$j_L^\mu = \bar{\Psi}\gamma^\mu\Pi^-\psi \qquad j_R^\mu = \bar{\Psi}\gamma^\mu\Pi^+\psi$

relations:

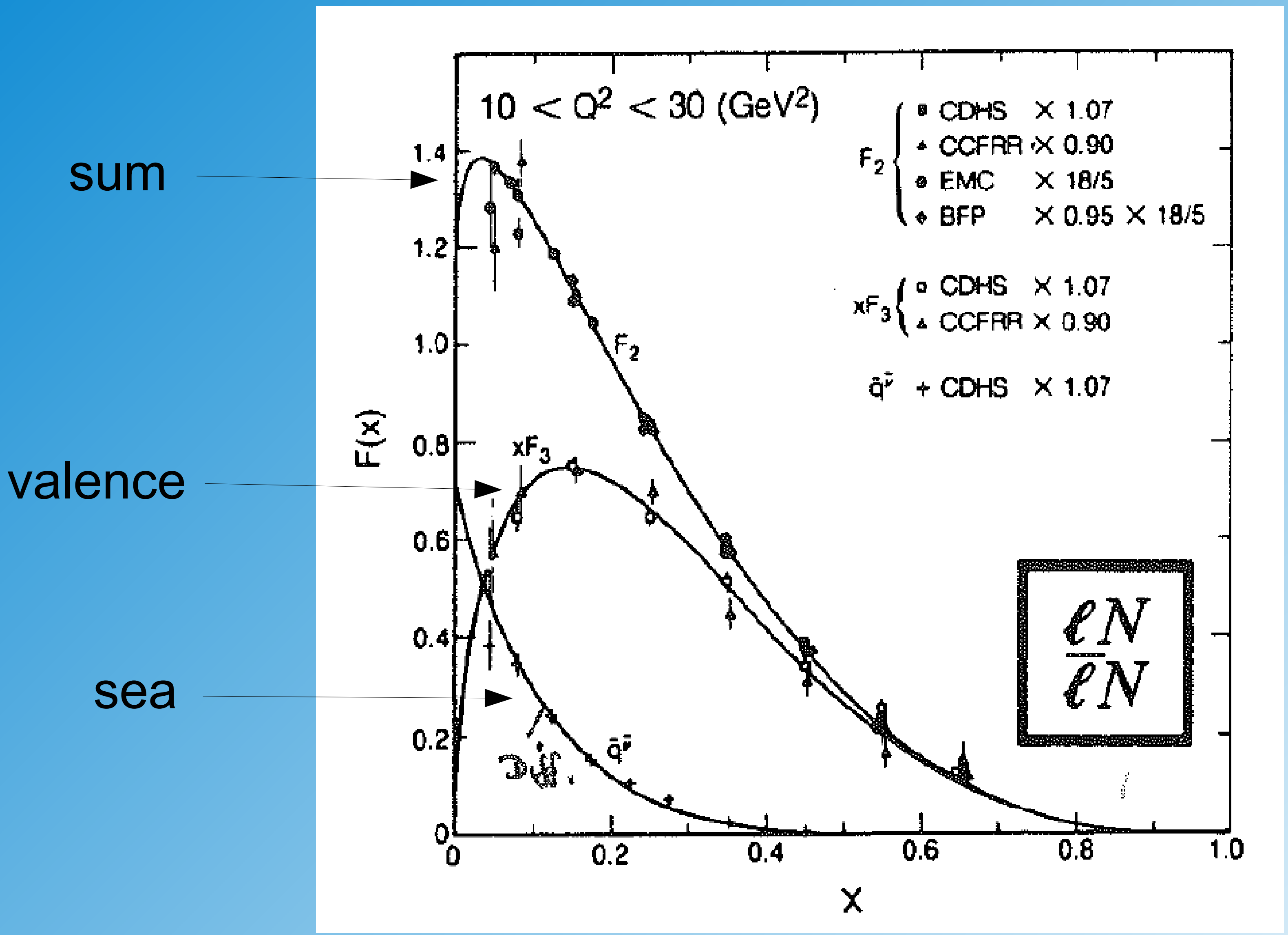
$j_L^\mu = 1/2\,(j_V^\mu - j_A^\mu)$ weak interaction (V-A theory):

$j_R^\mu = 1/2\,(j_V^\mu + j_A^\mu)$

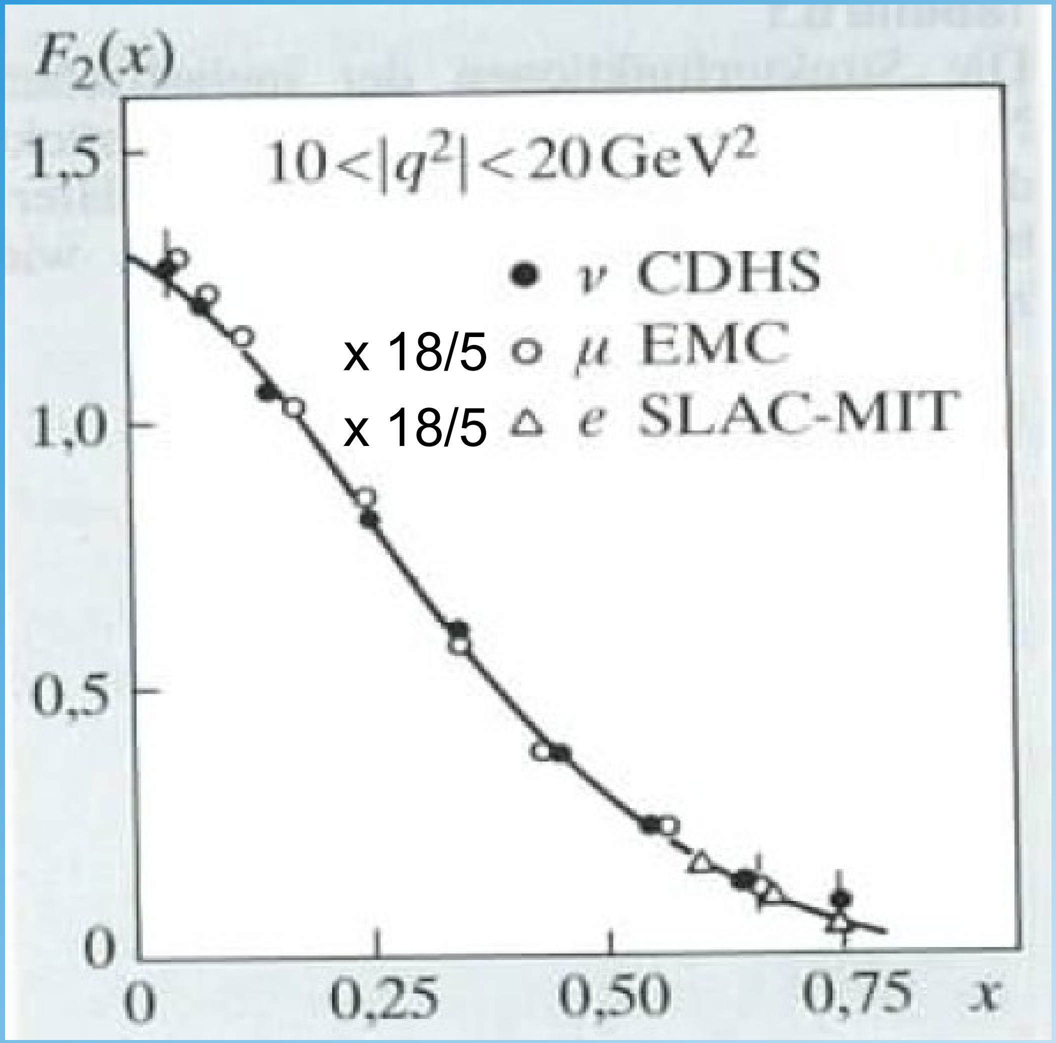
W-Propagator Effect



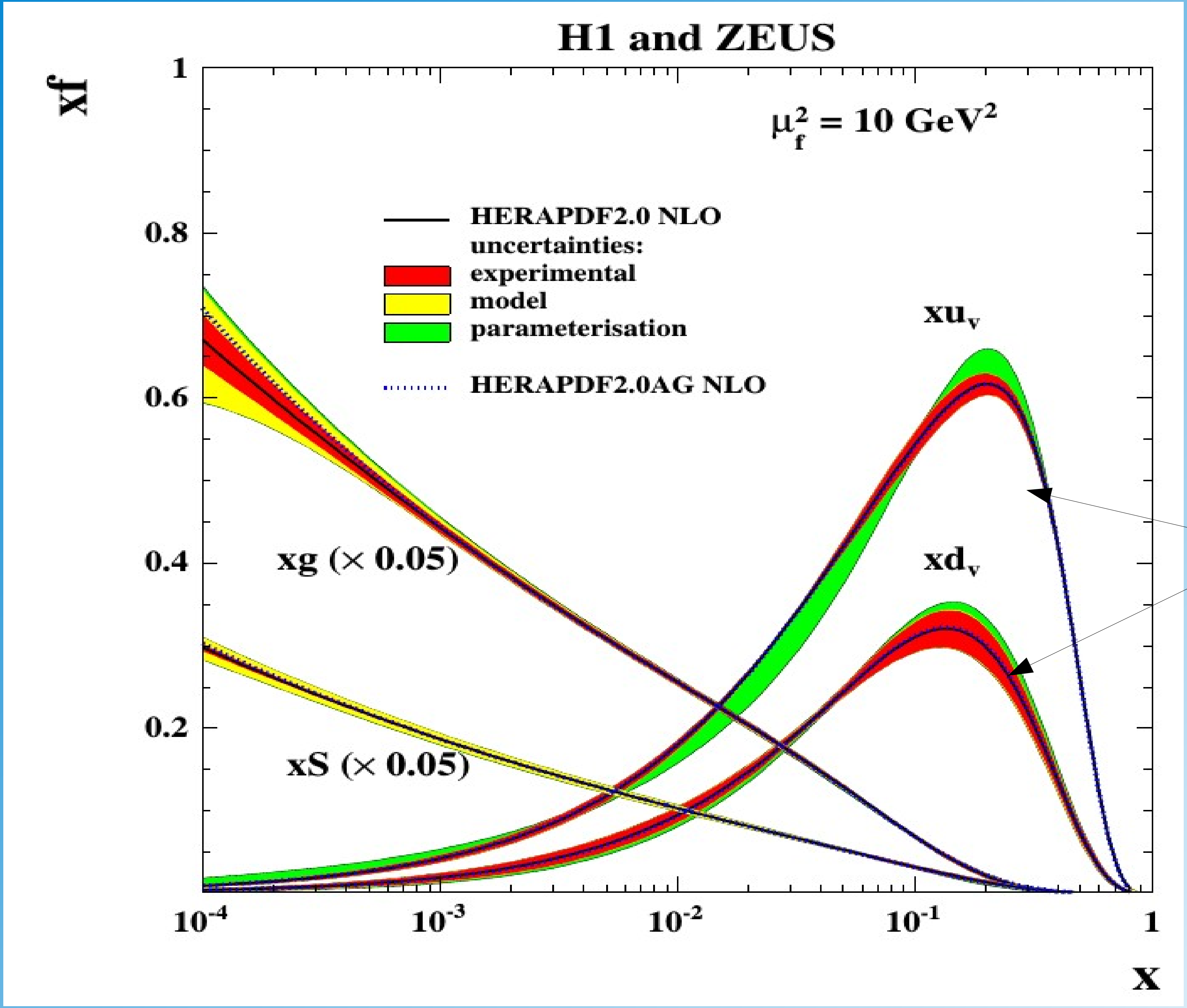
F_2 and F_3 in Neutrino-Scattering



Measurement of F_2



Fits of Parton Densities



constraints from $e\,p \rightarrow \nu\,X$ (CC)

Charged Current Event at H1 (HERA)