Riassunto della lezione precedente

• relazione di Callan-Gross e natura fermionica dei partoni

• definizioni di distribuzioni partoniche di valenza, del mare, di singoletto

• test del modello a partoni per DIS elettrone−nucleone;
caratteristiche delle distribuzioni di valenza e del mare

• necessità di allargare il campo di indagine anche a DIS con (anti)neutrino
per sondare nuovi flavors e processi di violazione di parità;
brevi cenni introduttivi al settore elettrodebole del Modello Standard

Genesi del Modello Standard elettrodebole

(brevi cenni)

- prime ipotesi (Feynmann Gell-Mann, '58 ; Glashow, '61) :
  interazioni deboli cariche ($W^\pm$) legate a interazione e.m. isovettoriale (γ) da rotazione di isospin; i leptoni e i quark sinistrorsi (left-handed) sono quindi organizzati in doppietti di isospin debole T secondo la simmetria $SU(2)_T$

$$\begin{pmatrix} \nu_e \\ e^- \end{pmatrix}_L \quad \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix}_L \quad \begin{pmatrix} u \\ d_\theta \end{pmatrix}_L \quad \begin{pmatrix} ? \\ s_\theta \end{pmatrix}_L$$

dove $d_\theta = d \cos\theta_C + s \sin\theta_C$; $s_\theta = -d \sin\theta_C + s \cos\theta_C$ θ_C angolo di Cabibbo

d , s autostati di interazione forte

d_θ , s_θ autostati di interazione debole

Commenti: • necessità di un quarto flavor, il quark charm (scoperto nel '74)

• transizioni left-handed tra ν e e^-/μ^- , tra quarks, via $W^\pm$
d_θ , s_θ spiegano reazioni del tipo $K^\pm \to \mu^\pm \nu$

Genesi….. (continua)

- ipotesi della carica debole *Y* (Glashow, '61): ulteriore struttura $U(1)_Y$

  i quark hanno carica e.m. $e_f = Y + ½ \, T_3$
  carica debole $Y = ½ \, (B + S)$
  riepilogo dei numeri quantici

	B	S	Y	T_3	e_f
u	$\frac{1}{3}$	0	$\frac{1}{6}$	1	$\frac{2}{3}$
d	$\frac{1}{3}$	0	$\frac{1}{6}$	-1	$-\frac{1}{3}$
s	$\frac{1}{3}$	-1	$-\frac{1}{3}$	0	$-\frac{1}{3}$

- teoria elettrodebole: i fermioni interagiscono attraverso i bosoni di gauge $\boldsymbol{W}$, B

$$\mathcal{L}_{\text{weak}} = g\bar{\psi}\,\frac{\mathbf{T}}{2}\,\psi \cdot \mathbf{W} + g'\bar{\psi}\,Y\,\psi\,B^0$$

g , g' couplings incognite

invarianza per $SU(2)_T \otimes U(1)_Y$ e fermioni / bosoni di gauge massless
⇒ teoria rinormalizzabile non-abeliana, perche` $[W_i, W_j] = i\,\varepsilon_{ijk}\,W_k$

Ma $m_W \neq 0$! Altrimenti si vedrebbe in β / *K* decays

Genesi…. (continua)

- ('t Hooft, '71) : teorie non-abeliane rimangono rinormalizzabili se masse sono generate dinamicamente da rottura spontanea della simmetria di gauge (meccanismo di Goldstone, '64; Higgs, '64…)

- rottura spontanea della simmetria implica ***W***, *B* → *W* ±, *Z*0, *A*
  in particolare

$$\begin{aligned} A &= \cos\theta_W B + \sin\theta_W W_3 \\ Z^0 &= -\sin\theta_W B + \cos\theta_W W_3 \end{aligned}$$

θ_W angolo di Weinberg

$$\mathcal{L}_{\text{weak}} = g\bar{\psi}\,\frac{\mathbf{T}}{2}\,\psi\,\cdot\mathbf{W} + g'\bar{\psi}\,Y\,\psi\,B^0$$

$$\begin{aligned} e_f &= Y + \frac{T_3}{2} \\ g' &= g\tan\theta_W \end{aligned}$$

$$\mathcal{L}_{\text{weak}} = g\bar{\psi}\,\frac{T^{\mp}}{2}\,\psi\,\cdot W^{\pm}$$

$$+g\sin\theta_W\bar{\psi}\,e_f\,\psi\,A + \frac{g}{\cos\theta_W}\,\bar{\psi}\left(\frac{T_3}{2} - e_f\sin^2\theta_W\right)\psi\,Z^0$$

$g\sin\theta_W \equiv e$

↓

$$+e\bar{\psi}\,e_f\,\psi\,A + \frac{2e}{2\sin\theta_W\cos\theta_W}\,\bar{\psi}\left(\frac{T_3}{2} - e_f\sin^2\theta_W\right)\psi\,Z^0$$

↓ corrente e.m. → $A \equiv \gamma$

↓ correnti debole neutre

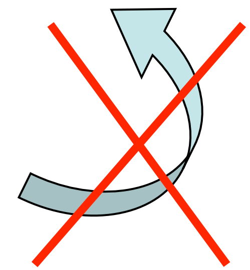
Rottura spontanea della simmetria : meccanismo di Goldstone

Esempio: teoria di campo per particella scalare ϕ

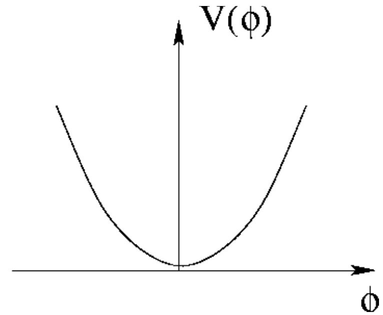
$$\mathcal{L}(\phi) = \frac{1}{2}(\partial_\mu \phi)^2 - V(\phi)$$

$$V(\phi) = \mu^2 \phi^2 + \lambda \phi^4 \quad , \qquad \lambda > 0$$

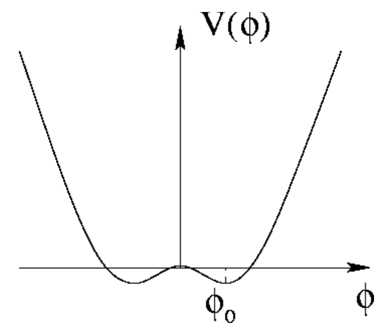
simmetria
$\mathcal{L}(-\phi) = \mathcal{L}(\phi)$



vuoto ≡ $\dfrac{\partial V}{\partial \phi} = 0$ $\xrightarrow{\mu^2 > 0}$ $\phi_0 = 0$



$\xrightarrow{\mu^2 < 0}$ $\phi_0 = \pm\sqrt{\dfrac{-\mu^2}{2\lambda}}$



nuovo campo $\phi' = \phi - \phi_0$; $\qquad \phi'_0 = 0$

$$V(\phi') = \mu^2(\phi' + \phi_0)^2 + \lambda(\phi' + \phi_0)^4 = -2\mu^2 \phi'^2 + o(\phi'^3)$$

$$m_{\phi'} = \sqrt{-4\mu^2}$$

$$\mathcal{L}(\phi') = \frac{1}{2}\left(\partial_\mu \phi'\right)^2 + 2\mu^2 \phi'^2 + ... = \underbrace{\frac{1}{2}\left(\partial_\mu \phi'\right)^2 - \frac{1}{2} m_\phi^2 \phi'^2}_{\mathcal{L}_{free}(\phi')} + ...$$

Riepilogo

settore elettrodebole del Modello Standard
=
teoria non-abeliana rinormalizzabile
delle interazioni e.m. e debole unificate
in simmetria di gauge $SU(2)_T$ - $U(1)_Y$

Predizioni :

- necessità di un quarto flavor, il quark charm
- 4 bosoni di gauge: γ , $W^{\pm}$, Z^0
- γ accoppiato a corrente conservata $\rightarrow$ massless (ok con QED)
- rapporto $\dfrac{\text{weak strength}}{\text{e.m. strength}}$ sperimentale si spiega se il coupling

  costante di Fermi $G_F = \dfrac{e^2}{4\sqrt{2}M_W^2 \sin^2\theta_W}$ con $M_W \sim 75$ GeV

  risulta inoltre $M_W^2 = M_Z^2 \cos^2\theta_W \rightarrow M_Z \geq M_W$

- correnti deboli cariche: $W^{\pm}$ producono transizioni

  $\nu \leftrightarrow e^-$, $u \leftrightarrow d$, $u \leftrightarrow s$ (cambio di stranezza) , ….
- correnti deboli neutre: $\nu + p \rightarrow \nu + p$, …

Conferme sperimentali:

- quark charm osservato nella risonanza J / ψ (BNL, 1974)

- bosoni di gauge $W^{\pm}$, Z^0 osservati nell'exp. UA1 (CERN, 1983)

Nobel 1984: Rubbia, van der Meer

- dal Particle Data Group: $M_W = 80.22 \pm 0.0026$ GeV

$$M_Z = 91.187 \pm 0.007 \text{ GeV}$$

$$\sin^2 \theta_W (M_Z) = 0.2319 \pm 0.0005$$

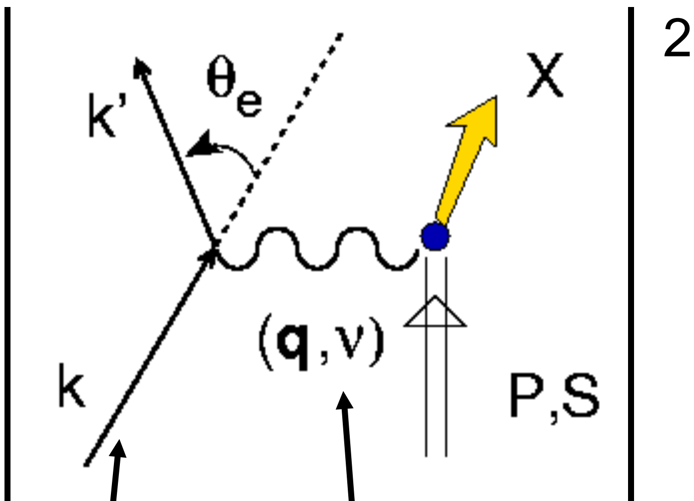
- si spiegano correnti deboli cariche con cambio di stranezza $K^{\pm} \rightarrow \mu^{\pm} \nu$

- correnti deboli neutre osservate al CERN nel 1973

Benvenuti *et al*., PRL **32** 800 (74)
Hasert et al., PL **B46** 138 (73)

- correnti deboli neutre non cambiano la stranezza (no $K^0 \rightarrow \mu^+ \mu^-$)
  cancellazioni seguono da $m_q << M_W$ e da esistenza di quark c con
  mixing $c \leftrightarrow - d \sin \theta_W + s \cos \theta_W$

Deep Inelastic Scattering



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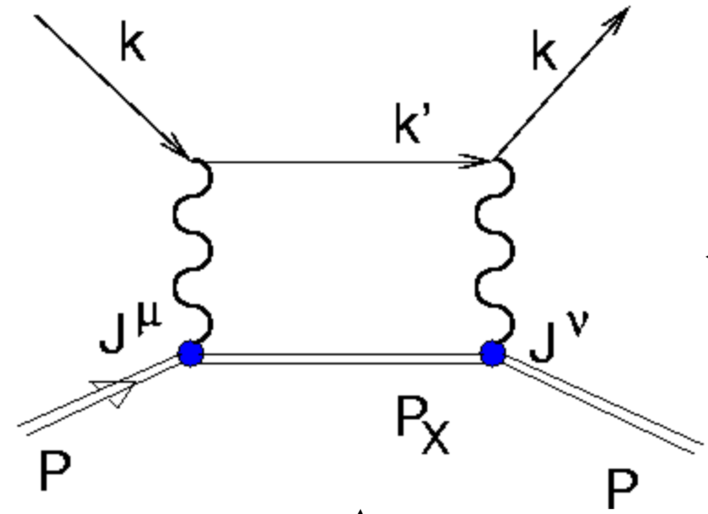


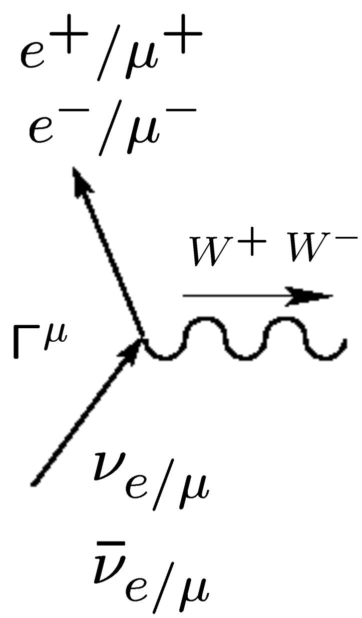
$e^{\pm}, \mu^{\pm},$
$\nu_{e/\mu}, \bar{\nu}_{e/\mu}$

$\gamma^{*}, W^{\pm}, Z^{0}$

Tensore leptonico $L^{\mu\nu}$

Tensore adronico $W^{\mu\nu}$

Tensore leptonico



interazione e.m. (e^- / μ^- left-handed) → scambio di γ

$$\Gamma^\mu = e\gamma^\mu$$

fascio di neutrini (left-handed) → scambio di W^+
(ma anche in reazioni inverse del tipo $e^+/\mu^+ \to \bar{\nu}_{e/\mu}$)

$$\Gamma^\mu = \frac{e}{2\sqrt{2}\sin\theta_W}\frac{T_3(=+1)}{2}\gamma^\mu(1-\gamma_5) \qquad V - A$$

fascio di antineutrini (right-handed) → scambio di W^-
(ma anche in reazioni inverse del tipo $e^-/\mu^- \to \nu_{e/\mu}$)

$$\Gamma^\mu = \frac{e}{2\sqrt{2}\sin\theta_W}\frac{T_3(=-1)}{2}\gamma^\mu(1+\gamma_5) \qquad V + A$$

$$\begin{aligned} L^{\mu\nu} &= \mathrm{Tr}\left[\Gamma^\mu\ \not{k}'\ \Gamma^\nu\ \not{k}\right] \\ &= \frac{e^2}{8\sin^2\theta_W}\frac{1}{4}\Big\{\underbrace{\mathrm{Tr}\left[\gamma^\mu\gamma^\alpha\gamma^\nu\gamma^\beta\right] k'_\alpha k_\beta}_{V\text{-}V} + \underbrace{\mathrm{Tr}\left[\gamma^\mu\gamma_5\gamma^\alpha\gamma^\nu\gamma_5\gamma^\beta\right] k'_\alpha k_\beta}_{A\text{-}A} \\ &\mp \mathrm{Tr}\left[\gamma^\mu\gamma^\alpha\gamma^\nu\gamma_5\gamma^\beta\right] k'_\alpha k_\beta \mp \mathrm{Tr}\left[\gamma^\mu\gamma_5\gamma^\alpha\gamma^\nu\gamma^\beta\right] k'_\alpha k_\beta\Big\} \longleftarrow V\text{-}A \end{aligned}$$

Tensore leptonico (continua)

$$
\begin{aligned}
\text{Tr}\left[\gamma^\mu\gamma^\alpha\gamma^\nu\gamma^\beta\right] &= \text{Tr}\left[\gamma^\mu\gamma_5\gamma^\alpha\gamma^\nu\gamma_5\gamma^\beta\right] = 4(g^{\mu\alpha}g^{\nu\beta} + g^{\mu\beta}g^{\nu\alpha} - g^{\mu\nu}g^{\alpha\beta}) \\
\text{Tr}\left[\gamma^\mu\gamma_5\gamma^\alpha\gamma^\nu\gamma^\beta\right] &= \text{Tr}\left[\gamma^\mu\gamma^\alpha\gamma^\nu\gamma_5\gamma^\beta\right] = 4i\epsilon^{\mu\nu\alpha\beta}
\end{aligned}
$$

$$
\begin{aligned}
L^{\mu\nu} &= \frac{e^2}{8\sin^2\theta_W}\, 2\left(k'^\mu k^\nu + k'^\nu k^\mu - k\cdot k' g^{\mu\nu} \mp i\epsilon^{\mu\nu\alpha\beta}k'_\alpha k_\beta\right) \\
&\equiv \qquad L^{\mu\nu(S)} \qquad\qquad \pm \quad L^{\mu\nu(A)}
\end{aligned}
$$

parte antisimmetrica del tensore è memoria dell' interferenza tra corrente debole vettoriale ed assiale

Propagatore del bosone vettore

si approssima con $$\left(-g^{\mu\nu} + \frac{q^\mu q^\nu}{q^2}\right) \frac{1}{q^2 - M_W^2} \sim -\frac{g^{\mu\nu}}{q^2 - M_W^2}$$

perché $$\frac{q^\mu q^\nu}{q^2} \sim \left(\frac{m_e}{M_W}\right)^2 \sim 0$$

Tensore adronico

- 2 vettori indipendenti P, q
- base tensoriale: $b_1 = g^{\mu\nu}$, $b_2 = q^\mu q^\nu$, $b_3 = P^\mu P^\nu$,
  $b_4 = (P^\mu q^\nu + P^\nu q^\mu)$, $b_5 = (P^\mu q^\nu - P^\nu q^\mu)$,
  $b_6 = \varepsilon_{\mu\nu\rho\sigma}\, q^\rho P^\sigma$
- tensore adronico $W^{\mu\nu} = \Sigma_i\, c_i\,(q^2, P \cdot q)\ b_i$
- Hermiticity $\rightarrow$ c_i sono reali
- invarianza per time-reversal $\rightarrow$ $c_5 = 0$
- corrente debole non conservata: $q_\mu W^{\mu\nu} \neq 0 \rightarrow c_6 \neq 0$
- c_1 e c_3 dipendenti da c_2 e c_4

$$W^{\mu\nu} = \underbrace{\left(-g^{\mu\nu} + \frac{q^\mu q^\nu}{q^2}\right) q^2\, c_2(q^2, P \cdot q)}_{W_1} + \underbrace{\frac{\widetilde{P}^\mu \widetilde{P}^\nu}{M^2}\left(-\frac{M^2 q^2}{P \cdot q}\right) c_4(q^2, P \cdot q)}_{W_2}$$

$$+ \underbrace{i\epsilon^{\mu\nu\rho\sigma}\frac{P_\rho q_\sigma}{M^2}\, c_6(q^2, P \cdot q)}_{\boxed{W_3}}$$

$$\underbrace{W_1 \qquad W_2}_{W^{(S)\mu\nu}}$$

$$\boxed{W^{(A)\mu\nu}}$$

violazione di parità

Ampiezza di scattering

$$
\begin{aligned}
L_{\mu\nu} &= L_{\mu\nu}^{(S)} \pm L_{\mu\nu}^{(A)} \\
W^{\mu\nu} &= W^{(S)\mu\nu} + W^{(A)\mu\nu}
\end{aligned}
\quad \Rightarrow \quad
\begin{aligned}
L_{\mu\nu} W^{\mu\nu} = \; & L_{\mu\nu}^{(S)} W^{(S)\mu\nu} \\
& \pm L_{\mu\nu}^{(A)} W^{(A)\mu\nu}
\end{aligned}
$$

$$
L_{\mu\nu} W^{\mu\nu} \overset{TRF}{\propto} \frac{e^4}{64 \sin^4 \theta_W} 4 E E' \cos^2 \frac{\theta_e}{2}
$$

$$
\times \left[W_2 + 2 W_1 \tan^2 \frac{\theta_e}{2} \pm \frac{E + E'}{M} W_3 \tan^2 \frac{\theta_e}{2} \right]
$$

interferenza *VA* → antisimmetria tra leptoni / antileptoni

Sezione d' urto

$$
\begin{aligned}
\frac{d\sigma^{\nu/\bar\nu}}{dE'd\Omega} &= \frac{\alpha^2}{64\sin^4\theta_W}\,\frac{E'}{E}\,\frac{1}{(Q^2+M_W^2)^2}\,L_{\mu\nu}\,W^{\mu\nu} \\
&= \frac{\alpha^2}{64\sin^4\theta_W}\,\frac{E'}{E}\,\frac{1}{(Q^2+M_W^2)^2}\,4EE'\cos^2\frac{\theta_e}{2} \\
&\qquad \times\left[W_2 + 2W_1\tan^2\frac{\theta_e}{2} \pm \frac{E+E'}{M}W_3\tan^2\frac{\theta_e}{2}\right]
\end{aligned}
$$

Limite DIS :
scaling in
dσ elastica

$$
W_1 \to \frac{F_1}{M} \qquad W_2 \to \frac{F_2}{\nu} \qquad W_3 \to \frac{F_3}{\nu}
$$

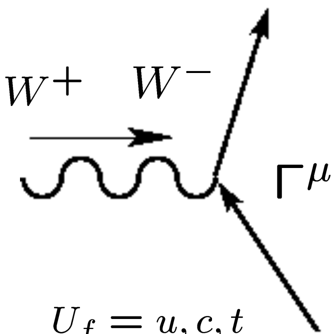
$$
\begin{aligned}
&= \frac{G_F^2}{8\pi^2}\left(\frac{M_W^2}{Q^2+M_W^2}\right)^2 E'^2\cos^2\frac{\theta_e}{2} \\
&\qquad \times\left[\frac{F_2}{\nu} + 2\frac{F_1}{M}\tan^2\frac{\theta_e}{2} \pm \frac{E+E'}{M\nu}F_3\tan^2\frac{\theta_e}{2}\right]
\end{aligned}
$$

$$
G_F = \frac{e^2}{4\sqrt{2}M_W^2\sin^2\theta_W}
$$

Vertice elettrodebole elementare in correnti cariche

$D_f = d, s, b$ $\quad$ $\bar{U}_{\bar{f}} = \bar{u}, \bar{c}, \bar{t}$

$U_f = u, c, t$ $\quad$ $\bar{D}_{\bar{f}} = \bar{d}, \bar{s}, \bar{b}$



$U_f = u, c, t$ $\quad$ $\bar{D}_{\bar{f}} = \bar{d}, \bar{s}, \bar{b}$

$D_f = d, s, b$ $\quad$ $\bar{U}_{\bar{f}} = \bar{u}, \bar{c}, \bar{t}$

interazione e.m. → scambio di γ

$$\Gamma^\mu = e\gamma^\mu$$

quark (left-handed)

$$\Gamma^\mu = \frac{e}{2\sqrt{2}\sin\theta_W} \frac{T_3(=+1)}{2} \gamma^\mu (1-\gamma_5) \sum_{f'} V_{ff'}$$

antiquark (right-handed)

$$\Gamma^\mu = \frac{e}{2\sqrt{2}\sin\theta_W} \frac{T_3(=-1)}{2} \gamma^\mu (1+\gamma_5) \sum_{\bar{f}'} V_{\bar{f}\bar{f}'}$$

$$\begin{pmatrix} U_f \\ D_f \end{pmatrix} \equiv \begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$$

$$V_{U_f D_f} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \in SU_f(3)$$

$$\sim \begin{pmatrix} \cos\theta_C & \sin\theta_C & 0 \\ -\sin\theta_C & \cos\theta_C & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\sum_{f'} \left| V_{U_f D_{f'}} \right|^2 = 1$$

Tensore adronico elementare

$$
\begin{aligned}
2mW^{\mathrm{el}\,\mu\nu} &= \frac{1}{2\pi}\int \frac{d\mathbf{p}'}{(2\pi)^3 2p'^0}\,(2\pi)^4\delta(p'-p-q)\,H^{\mathrm{el}\,\mu\nu} \\
&= \frac{1}{2M\nu}\,\delta\,(x-x_B)\;H^{\mathrm{el}\,\mu\nu}
\end{aligned}
$$

$$
\begin{aligned}
H^{\mathrm{el}\mu\nu} &= \frac{e_f^2}{4}\,\mathrm{Tr}\,\left[\,(x\,\not{P}+\not{q}+m)\,\gamma^\mu\,(1\mp\gamma_5)\,(x\,\not{P}+m)\,\gamma^\nu\,(1\mp\gamma_5)\right] \\
&\qquad \times\sum_{f'}\left|V_{U_f D_{f'}}\right|^2 \\
&= H^{\mathrm{el}(S)\mu\nu}\pm H^{\mathrm{el}(A)\mu\nu}
\end{aligned}
$$

Poi $\quad L_{\mu\nu}\,H^{\mathrm{el}\mu\nu}=L_{\mu\nu}^{(S)}\,H^{\mathrm{el}(S)\mu\nu}\pm L_{\mu\nu}^{(A)}\,H^{\mathrm{el}(A)\mu\nu}$

Funzioni di struttura

$$\frac{d\sigma}{dE'd\Omega}(P,q) = \sum_{f,\bar{f}} \int_0^1 dx \, \frac{d\sigma^{\text{el}}}{dE'd\Omega}(xP,q) \, \phi_f(x)$$

$$\Downarrow$$

$$F_2(x_B) = x_B \sum_f \left[\phi_f(x_B) + \bar{\phi}(x_B)\right]$$

$$2x_B F_1(x_B) = F_2(x_B)$$

$$\boxed{F_3(x_B) = \sum_f \left[\phi_f(x_B) - \bar{\phi}(x_B)\right]}$$

non-singlet flavor
asimmetria right-/left- handed (*V/A*)
può cambiare il flavor

$SU_f(3)$ $\rightarrow$ 12 incognite :

$$u_p, d_p, s_p, \bar{u}_p, \bar{d}_p, \bar{s}_p$$
$$u_n, d_n, s_n, \bar{u}_n, \bar{d}_n, \bar{s}_n$$

8 misure possibili :

$$F_2^{W^+p}, F_2^{W^-p}, F_3^{W^+p}, F_3^{W^-p}$$
$$F_2^{W^+n}, F_2^{W^-n}, F_3^{W^+n}, F_3^{W^-n}$$

invarianza di isospin :
(2 relazioni)

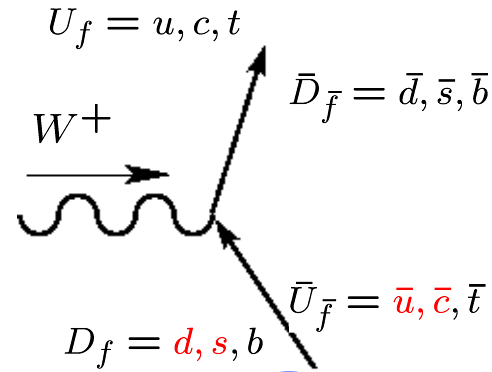
$$u_p \equiv d_n \qquad d_p \equiv u_n$$

simmetria di isospin del "mare" :
(2 relazioni)

$$\boxed{\bar{u} = \bar{d}}$$

Sistema determinato: da DIS (anti)neutrino – Nucleone si possono estrarre le distribuzioni degli (anti)quark per i tre flavor

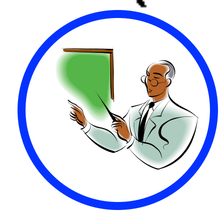
Esempio : $\nu_{e/\mu} + p \to e^-/\mu^- + X$



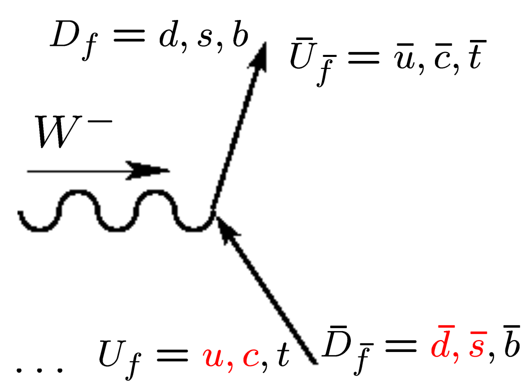
$$
\begin{aligned}
J^\mu_{W^+} \;\propto\;& \bar{u}\,\gamma^\mu(1-\gamma_5)\,[d\cos\theta_C + s\sin\theta_C] \\
+\;& \bar{c}\,\gamma^\mu(1-\gamma_5)\,[s\cos\theta_C - d\sin\theta_C] + \text{antiquarks}\ldots
\end{aligned}
$$

$$
\frac{F_2(x_B)}{x_B} = 2F_1(x_B) \sim 2\,[d(x_B) + s(x_B) + \bar{u}(x_B) + \bar{c}(x_B)] + \ldots
$$

$$
F_3(x_B) \sim 2\,[d(x_B) + s(x_B) - \bar{u}(x_B) - \bar{c}(x_B)] + \ldots
$$



$\bar{\nu}_{e/\mu} + p \to e^+/\mu^+ + X$



$$
\begin{aligned}
J^\mu_{W^-} \;\propto\;& [\bar{d}\cos\theta_C + \bar{s}\sin\theta_C]\,\gamma^\mu(1-\gamma_5)\,u \\
+\;& [\bar{s}\cos\theta_C - \bar{d}\sin\theta_C]\,\gamma^\mu(1-\gamma_5)\,c \\
+\;& \overline{(\bar{u})}\,\gamma^\mu(1+\gamma_5)\,[\bar{d}\cos\theta_C + \bar{s}\sin\theta_C]\ldots
\end{aligned}
$$

$$
\left[V^{-1} = V^\dagger\right]
$$

$$
\frac{F_2(x_B)}{x_B} = 2F_1(x_B) = 2\left[\bar{d}(x_B) + \bar{s}(x_B) + u(x_B) + c(x_B)\right] + \ldots
$$

$$
F_3(x_B) = 2\left[-\bar{d}(x_B) - \bar{s}(x_B) + u(x_B) + c(x_B)\right] + \ldots
$$

Verifiche sperimentali

1) (anti)neutrino DIS su nuclei isoscalari (Z=N → n° u = n° d quarks)

$$\frac{\sigma(\nu A)}{\sigma(\bar{\nu} A)} \sim 3$$

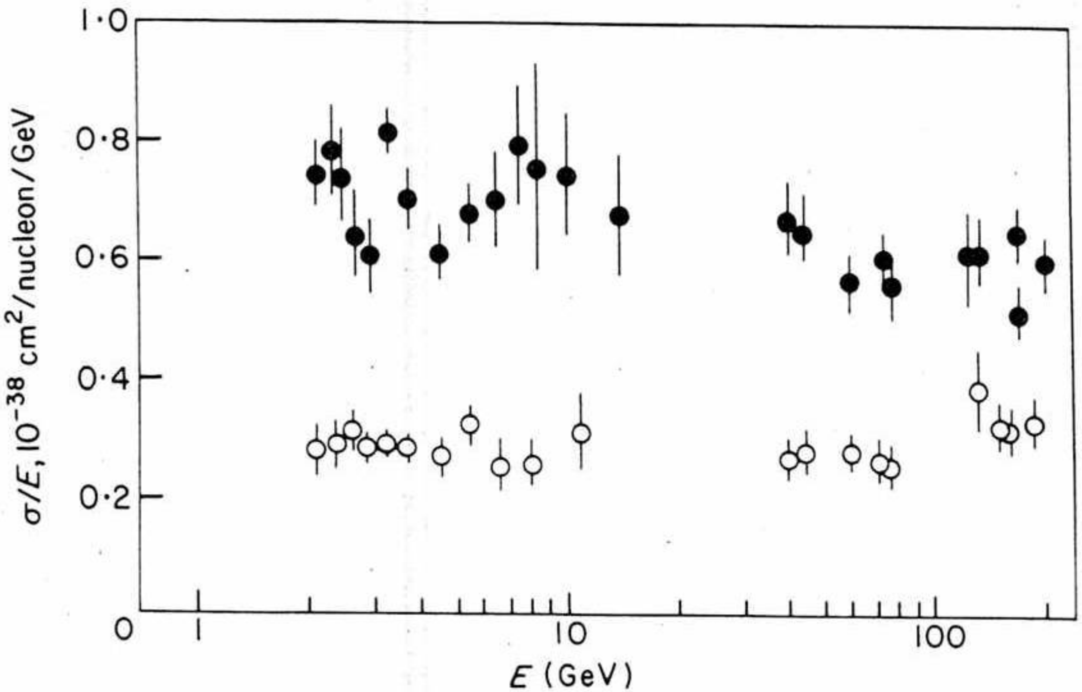


FIG. 11.12. $\sigma^{\bar{\nu}}/E$ and σ^{ν}/E for $E \leqslant 200$ GeV.

Dati dell'esp. Gargamelle
Perkins, Contemp. Phys. **16** 173 (75)

Interpretazione in QPM

$$\frac{d\sigma^{\nu/\bar{\nu}}}{dE'd\Omega} = \frac{G_F^2}{8\pi^2}\left(\frac{M_W^2}{Q^2+M_W^2}\right)^2 E'^2\cos^2\frac{\theta}{2}\left[\frac{F_2}{\nu}+2\frac{F_1}{M}\tan^2\frac{\theta}{2}\pm\frac{E+E'}{M\nu}F_3\tan^2\frac{\theta}{2}\right]$$

$$\frac{d\sigma^{\nu/\bar{\nu}}}{dx_B dy} = \frac{dE'd\Omega}{dx_B dy}\,\frac{d\sigma}{dE'd\Omega} = \frac{\pi 2M\nu}{E'}\,\frac{d\sigma}{dE'd\Omega}$$

$$\frac{d\sigma^{\nu/\bar{\nu}}}{dx_B dy} = \frac{G_F^2}{4\pi}\left(\frac{M_W^2}{Q^2+M_W^2}\right)^2 ME\left[F_1 x_B y^2 + F_2\left(1-y-\frac{Mx_B y}{2E}\right)\pm x_B\left(y-\frac{y^2}{2}\right)F_3\right]$$

$$\sim \frac{G_F^2}{4\pi}\left(\frac{M_W^2}{Q^2+M_W^2}\right)^2 ME\left[F_2\left(1-y+\frac{y^2}{2}\right)\pm x_B\left(y-\frac{y^2}{2}\right)F_3\right]$$

Interpretazione (continua)

approssimazioni : $\bar{u} = \bar{d} = \bar{c} = \bar{s} = \bar{t} = \bar{b} = t = b = 0$

$s \sim c \sim K$

$$\frac{d\sigma^{\nu A}}{dx_B dy} = N^{\nu A}\left[\left(1 - y + \frac{y^2}{2} - \frac{M_A x_B y}{2E}\right) F_2 + \left(y - \frac{y^2}{2}\right) x_B F_3\right]$$

$$\sim N^{\nu A} 2x_B (d + K)$$

$$F_2 = x_B F_3 = 2x_B (d + s)$$

$$\frac{d\sigma^{\bar{\nu} A}}{dx_B dy} = N^{\bar{\nu} A}\left[\left(1 - y + \frac{y^2}{2} - \frac{M_A x_B y}{2E}\right) F_2 - \left(y - \frac{y^2}{2}\right) x_B F_3\right]$$

$$\sim N^{\bar{\nu} A} 2x_B (u + K) (1 - y)^2$$

$$F_2 = x_B F_3 = 2x_B (u + c)$$

Interpretazione (continua)

$$\frac{\sigma^{\nu A}}{\sigma^{\bar{\nu} A}} = \frac{\int_0^1 dxdy\, d\sigma^{\nu A}}{\int_0^1 dxdy\, d\sigma^{\bar{\nu} A}} = \frac{N^{\nu A} \int_0^1 dx 2x(d+K)}{N^{\bar{\nu} A} \int_0^1 dx 2x(u+K)\, \frac{1}{3}} \sim 3$$

$$N^{\nu A} \equiv N^{\bar{\nu} A} = \frac{G_F^2}{4\pi} \left(\frac{M_W^2}{Q^2 + M_W^2} \right)^2 ME$$

nuclei isoscalari $\rightarrow$ $n_u = n_d$

N = { partoni a spin ½ con stessa interazione elettrodebole dei leptoni ; antipartoni soppressi }

N.B. deviazioni dovute a $s \neq c \neq K$ e per contributo di antiquarks