

Riassunto della lezione precedente

- importanza del momento trasverso intrinseco dei partoni
 - sezione d'urto più ricca → nuove possibilità per estrarre la trasversità
 - effetto Collins : meccanismo non perturbativo che lega spin del quark a moto orbitale dell'adrone finale

N.B. Funzione di Collins è naïve T-odd per FSI tra adrone e jet residuo
→ nuova classe di funzioni

- effetto Collins = prodotto di due incognite; universalità necessaria per estrarre info su funzione di Collins da corrispondente processo e^+e^-
- problema per processi elementari non collineari (no teoremi di fattorizzazione generali)
 - funzioni di frammentazione di interferenza (per due adroni)
- color-gauge invariance dei correlatori bilocali → operatore di gauge link
 - funzioni naïve T-odd permesse anche nello stato iniziale
 - struttura più ricca al leading twist → diverse nuove sorgenti di SSA

Invarianza per trasformazioni di $SU_c(3)$ di Φ e Δ

$$\Phi(x, S) = \int \frac{d^4\xi}{2\pi} e^{-ixP^+\xi^-} \langle P, S | \underbrace{\bar{\psi}(\xi^-) \psi(0)}_{\text{campi di quark a punti 4-dim. diversi}} | P, S \rangle \Big|_{\xi^+, \xi_\perp=0}$$

campi di quark a punti 4-dim. diversi

per $\psi(\xi) \rightarrow \exp[i\alpha(\xi)] \psi(\xi)$ si perde gauge invarianza

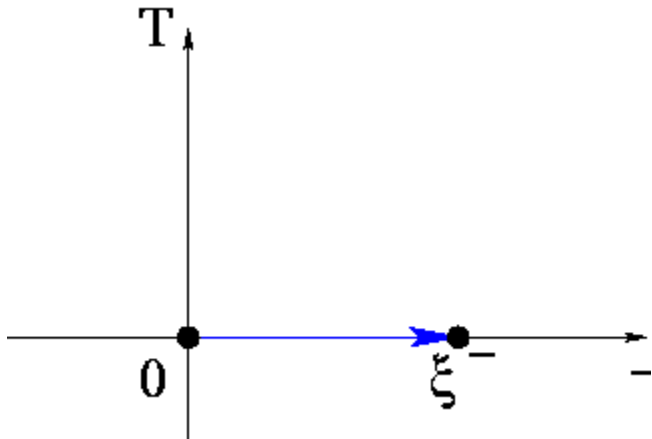
serve un operatore tale che $U(\xi_1, \xi_2) \rightarrow \exp[i\alpha(\xi_1)] U(\xi_1, \xi_2) \exp[-i\alpha(\xi_2)]$

gauge-link (tower) operator



$$\bar{\psi}(\xi^-) \psi(0) \longrightarrow \bar{\psi}(\xi^-) U_{[0, \xi^-]} \psi(0) \equiv \bar{\psi}(\xi^-) \mathcal{P} e^{-ig \int_0^{\xi^-} dw \cdot A(w)} \psi(0)$$

$$\bar{\psi}(\xi^-) \sum_{n=0}^{\infty} (-ig)^n \int_0^{\xi^-} dw_1^- A^+(w_1) \dots \int_{w_{n-1}^-}^{\xi^-} dw_n^- A^+(w_n) \Big|_{w_i^+ = \xi^+ = 0, w_{iT} = \xi_T = 0_T} \psi(0)$$



\mathcal{P} = sviluppo dell'esponenziale
ordinando i cammini di integrazione :
 $A^+(\phi, \mathbf{A}_T) \rightarrow \text{twist 2}$
 \mathbf{A}_T (indipendente) $\rightarrow \text{twist 3} \dots$

$A^+ = 0$ gauge \rightarrow def. precedente

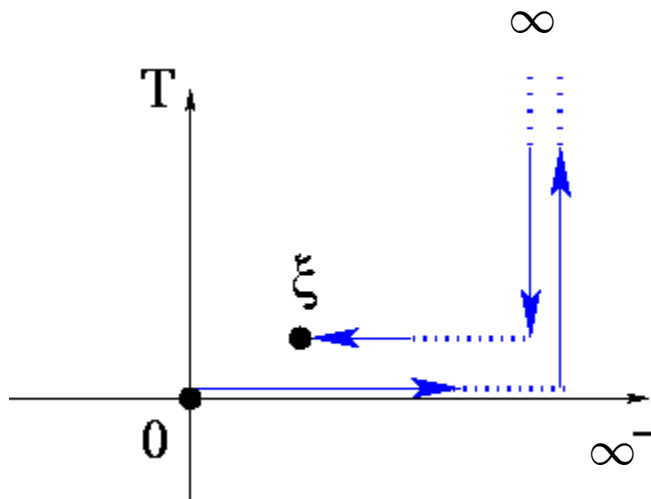
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$$\Phi(x, \mathbf{p}_T, S) = \int \frac{d^4 \xi}{(2\pi)^3} e^{-ixP^+ \xi^- + i\mathbf{p}_T \cdot \boldsymbol{\xi}_T} \underbrace{\langle P, S | \bar{\psi}(\xi) \psi(0) | P, S \rangle}_{\xi^+ = 0}$$



$$\bar{\psi}(\xi) \psi(0) \longrightarrow \bar{\psi}(\xi) U_{[0, \infty^-]} U_{[0, \infty^T]} U_{[\infty^T, \xi^T]} U_{[\infty^-, \xi^-]} \psi(0)$$

$\equiv \bar{\psi}(\xi) \psi(0)$ interpretazione probabilistica
al twist 2 preservata

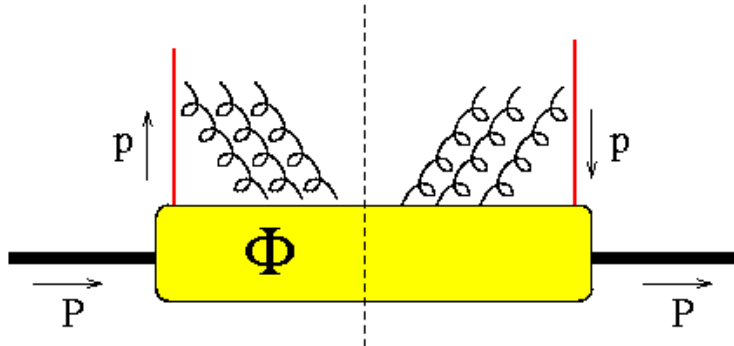
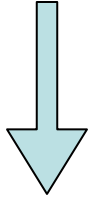


analisi in twist rivela che al twist 2
contribuiscono sia A^+ ,
che \mathbf{A}_T a $n_- = \infty$ eliminaibile in
axial gauge $A^+ = 0$
non eliminaibile nei gauge standard!

Φ invariante per trasformazioni di $SU_c(3)$

$$U_{[0,\xi^-]} = \mathcal{P}e^{-ig \int_0^{\xi^-} dw^- A^+(w^-)}$$

$$\approx 1 + (-ig) \int_0^{\xi^-} dw^- A^+(w^-) \Big|_{\dots} + (-ig)^2 \int_0^{\xi^-} dw_1^- A^+(w_1^-) \int_{w_1^-}^{\xi^-} dw_2^- A^+(w_2^-) \Big|_{\dots} + \dots$$



“FSI” tra quark e adrone via gluoni soffici
lungo direzione “+” e “T” a $n_+ = \infty$
 \Rightarrow strutture **T-odd** permesse

(Boer, Mulders, Pijlman, N.P.**B667**(’03)201)

$$\Phi[\gamma^+](x, \mathbf{p}_T, S) = f_1(x, \mathbf{p}_T^2) - \frac{\mathbf{p}_T \times \mathbf{S}_T \cdot \hat{\mathbf{P}}}{M} f_{1T}^\perp(x, \mathbf{p}_T^2)$$

$$\Phi[\gamma^+ \gamma_5](x, \mathbf{p}_T, S) = \lambda g_{1L}(x, \mathbf{p}_T^2) + \frac{\mathbf{p}_T \cdot \mathbf{S}_T}{M} g_{1T}(x, \mathbf{p}_T^2)$$

$$\Phi[i\sigma^{i+} \gamma_5](x, \mathbf{p}_T, S) = S_T^i h_{1T}(x, \mathbf{p}_T^2) + \frac{p_T^i}{M} \left[\lambda h_{1L}^\perp(x, \mathbf{p}_T^2) + \frac{\mathbf{p}_T \cdot \mathbf{S}_T}{M} h_{1T}^\perp(x, \mathbf{p}_T^2) \right]$$

$$+ \frac{(\mathbf{p}_T \times \hat{\mathbf{P}})_i}{M} h_1^\perp(x, \mathbf{p}_T^2)$$

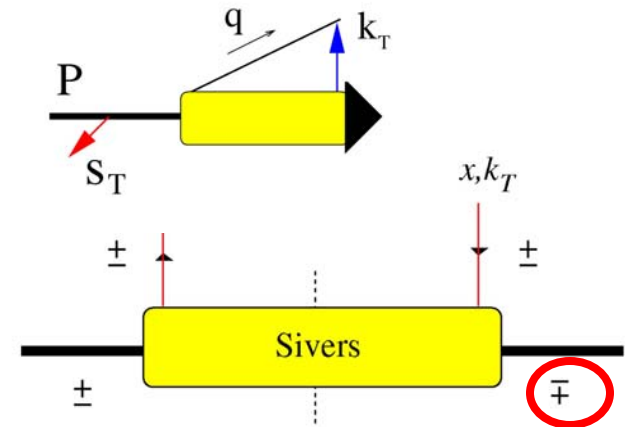
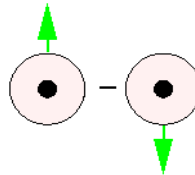
$$\int d\mathbf{p}_T \text{ (T-odd) } = 0$$

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$$f(q/p^\uparrow) = f_1^q(x, \mathbf{k}_T^2) - f_{1T}^{\perp q}(x, \mathbf{k}_T^2) \frac{\hat{\mathbf{P}} \times \mathbf{k}_T \cdot \mathbf{S}}{M}$$

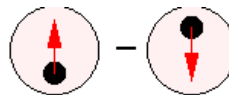
$$-f_{1T}^{\perp q}(x, \mathbf{k}_T^2) 2 \frac{\hat{\mathbf{P}} \times \mathbf{k}_T \cdot \mathbf{S}}{M} = f(q/p^\uparrow) - f(q/p^\downarrow)$$

funzione di Sivers

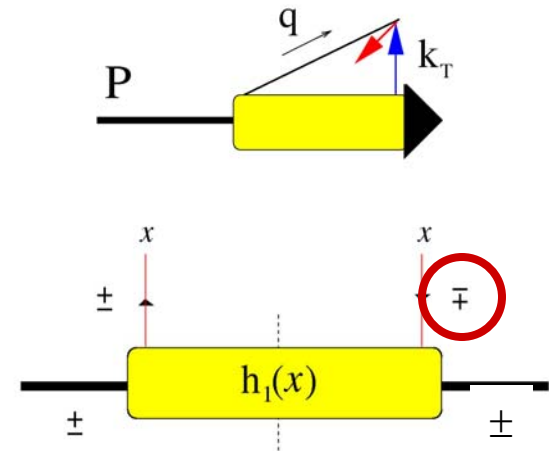


$$f(q^\uparrow/p) = \frac{1}{2} \left(f_1^q(x, \mathbf{k}_T^2) - h_1^{\perp q}(x, \mathbf{k}_T^2) \frac{\hat{\mathbf{P}} \times \mathbf{k}_T \cdot \mathbf{S}_q}{M} \right)$$

$$-h_1^{\perp q}(x, \mathbf{k}_T^2) \frac{\hat{\mathbf{P}} \times \mathbf{k}_T \cdot \mathbf{S}_q}{M} = f(q^\uparrow/p) - f(q^\downarrow/p)$$



funzione di Boer-Mulders

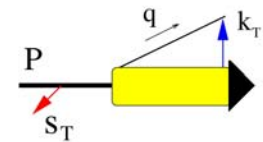


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PDF	chiral even		chiral-odd
	q non pol.	q^\rightarrow	q^\uparrow
N non pol.	f_1		h_1^\perp
$N^\rightarrow = L$		g_{1L}	h_{1L}^\perp
$N^\uparrow = T$	f_{1T}^\perp	g_{1T}	h_1, h_{1T}^\perp

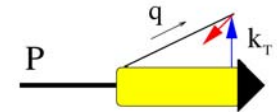
Sivers

$$f(q/p^\uparrow) = f_1^q(x, \mathbf{k}_T^2) - f_{1T}^{\perp q}(x, \mathbf{k}_T^2) \frac{\hat{\mathbf{P}} \times \mathbf{k}_T \cdot \mathbf{S}}{M}$$



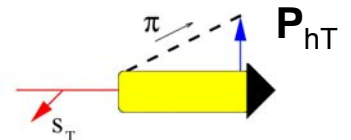
Boer-Mulders

$$f(q^\uparrow/p) = \frac{1}{2} \left(f_1^q(x, \mathbf{k}_T^2) - h_1^{\perp q}(x, \mathbf{k}_T^2) \frac{\hat{\mathbf{P}} \times \mathbf{k}_T \cdot \mathbf{S}_q}{M} \right)$$



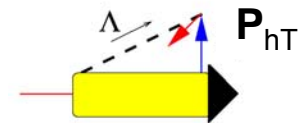
Collins

$$D(h/q^\uparrow) = D_1^q(z, \mathbf{P}_{hT}^2) + H_1^{\perp q}(z, \mathbf{P}_{hT}^2) \frac{\hat{\mathbf{k}} \times \mathbf{P}_{hT} \cdot \mathbf{S}_q}{zM_h}$$



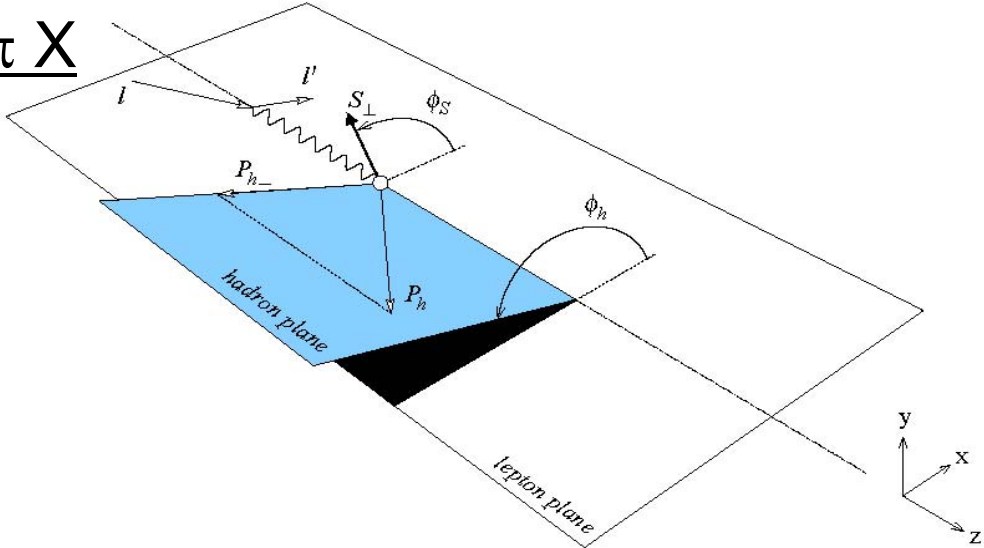
FF polarizzata

$$D(h^\uparrow/q) = \frac{1}{2} \left(D_1^q(z, \mathbf{P}_{hT}^2) + D_{1T}^{\perp q}(z, \mathbf{P}_{hT}^2) \frac{\hat{\mathbf{k}} \times \mathbf{P}_{hT} \cdot \mathbf{S}_h}{zM_h} \right)$$



Riconsideriamo SIDIS e $p^\uparrow \rightarrow e' \pi X$

sezione d'urto
a twist=2



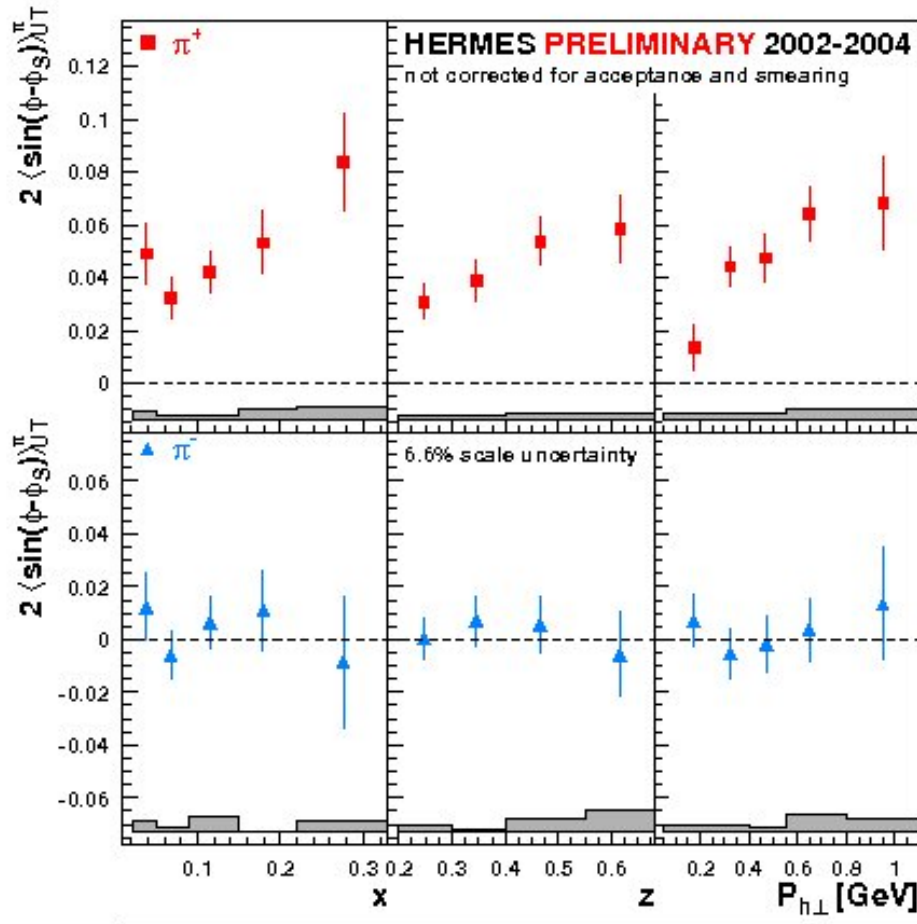
$$\frac{d^6\sigma_{OT}}{dx\,dy\,dz\,d\phi_S\,d\mathbf{P}_{h\perp}} = \frac{2\alpha^2}{sxy^2} \sum_{f\bar{f}} e_f^2 \Big\{ \\
A(y) \mathcal{F} \left[f_1^f(x, \mathbf{p}_T^2) D_1^f(z, \mathbf{k}_T^2) \right] \\
- B(y) \cos 2\phi_h \mathcal{F} \left[\frac{2\hat{\mathbf{P}}_{h\perp} \cdot \mathbf{p}_T \hat{\mathbf{P}}_{h\perp} \cdot \mathbf{k}_T - \mathbf{p}_T \cdot \mathbf{k}_T}{M M_h} h_1^\perp f(x, \mathbf{p}_T^2) H_1^\perp f(z, \mathbf{k}_T^2) \right] \\
+ |\mathbf{S}_T| B(y) \sin(\phi_h + \phi_S) \mathcal{F} \left[\frac{\mathbf{k}_T \cdot \hat{\mathbf{P}}_{h\perp}}{M_h} h_1^f(x, \mathbf{p}_T^2) H_1^\perp f(z, \mathbf{k}_T^2) \right] \quad \leftarrow \text{effetto Collins} \\
- |\mathbf{S}_T| B(y) \sin(\phi_h - \phi_S) \mathcal{F} \left[\frac{\mathbf{p}_T \cdot \hat{\mathbf{P}}_{h\perp}}{M} f_{1T}^\perp f(x, \mathbf{p}_T^2) D_1^f(z, \mathbf{k}_T^2) \right] \quad \leftarrow \text{effetto Sivers} \\
+ |\mathbf{S}_T| B(y) \sin(3\phi_h - \phi_S) \mathcal{F} \left[\frac{4(\hat{\mathbf{P}}_{h\perp} \cdot \mathbf{p}_T)^2 \hat{\mathbf{P}}_{h\perp} \cdot \mathbf{k}_T - 2\hat{\mathbf{P}}_{h\perp} \cdot \mathbf{p}_T \mathbf{p}_T \cdot \mathbf{k}_T - \mathbf{p}_T^2 \hat{\mathbf{P}}_{h\perp} \cdot \mathbf{k}_T}{M^2 M_h} \right. \\
\left. \times h_{1T}^\perp f(x, \mathbf{p}_T^2) H_1^\perp f(z, \mathbf{k}_T^2) \right] \Big\}$$

$$\phi_S \neq 0, \pi$$

i due effetti sono separabili in linea di principio ; operativamente ci sono difficoltà

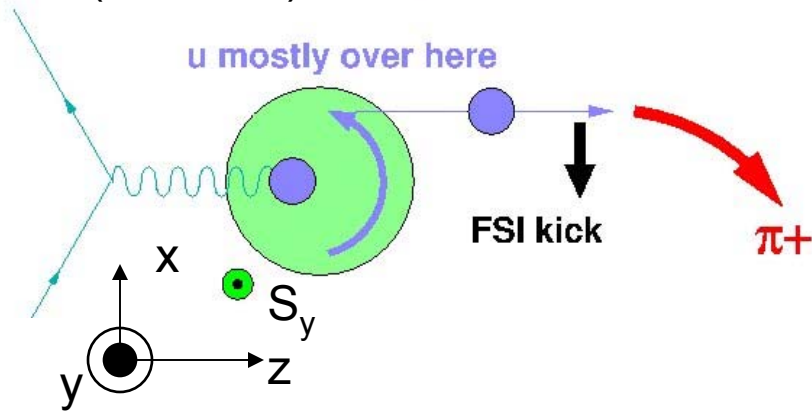
Effetto Sivers e relativa SSA

$$\frac{\int d\phi_S d\mathbf{P}_{h\perp} \frac{|\mathbf{P}_{h\perp}|}{M_h} \sin(\phi_h - \phi_S) (d\sigma^\uparrow - d\sigma^\downarrow)}{\int d\phi_S d\mathbf{P}_{h\perp} (d\sigma^\uparrow + d\sigma^\downarrow)} \propto -|\mathbf{S}_T| \frac{B(y)}{A(y)} \frac{\sum_{f\bar{f}} e_f^2 f_{1T}^{\perp f(1)}(x) D_1^f(z)}{\sum_{f\bar{f}} e_f^2 f_1^f(x) D_1^f(z)}$$



π^+ positivo; se $\sin(\phi_h - \phi_S) > 0$
 $\rightarrow f_{1T}^{\perp u}$ negativa
 $f_{1T}^{\perp d}$ positiva ? (piccola)

(continua)



$$\left. \begin{array}{l} \phi_S = \pi/2 \\ \phi = \pi \end{array} \right\} \sin(\phi - \phi_S) > 0$$

deflessione quark d a $x > 0$

possibile interpretazione:

$N^\uparrow \rightarrow$ distribuzione asimmetrica
nel piano trasverso: u va
a $x > 0$ e d va a $x < 0$

perché $S_y \neq 0 \rightarrow L_q \neq 0$

γ colpisce u che viene deflesso
a $x < 0$ per confinamento (forza
colore attrattiva); opposto per d
(Burkardt, Phys. Rev. D **66** ('02) 114005)

effetto diretto del momento
angolare orbitale dei quark



K. Bruhwieler - TJNAF - 2003

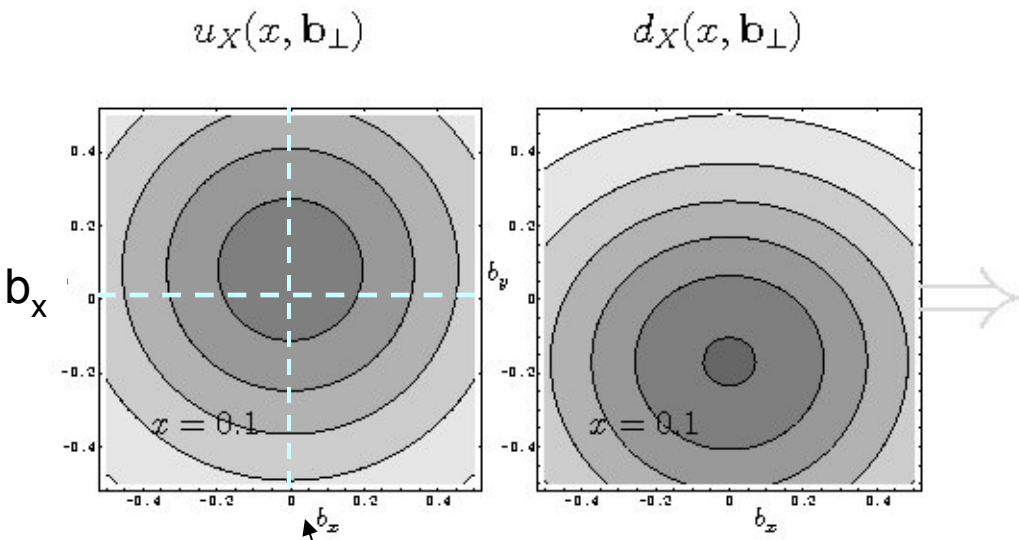
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distorsione nel piano trasverso della distribuzione di partoni provocata da polarizzazione trasversa del protone può essere descritta da

Generalized Parton Distribution E

→ legame PDF $f_{1T}^\perp(x,p_T) \leftrightarrow$ GPD $E(x,0,-\Delta_T^2)$

$$f_{q/p\uparrow}(x,\vec{b}_T) = f_1^q(x,\vec{b}_T^2) - \frac{1}{M} \frac{\partial}{\partial b_x} \int \frac{d\vec{\Delta}_T}{(2\pi)^2} E^q(x,0,-\vec{\Delta}_T^2) e^{-\vec{b}_T \cdot \vec{\Delta}_T}$$



$$\int dx E^q(x,0,0) = \kappa^q$$

calcolo su reticolo dà
 $\partial \hat{E}^u(x,\mathbf{b}_T) / \partial b_x > 0$ cioè
 $f_{1T}^\perp u < 0$
 opposto per quark d
 $f_{1T}^\perp d > 0$

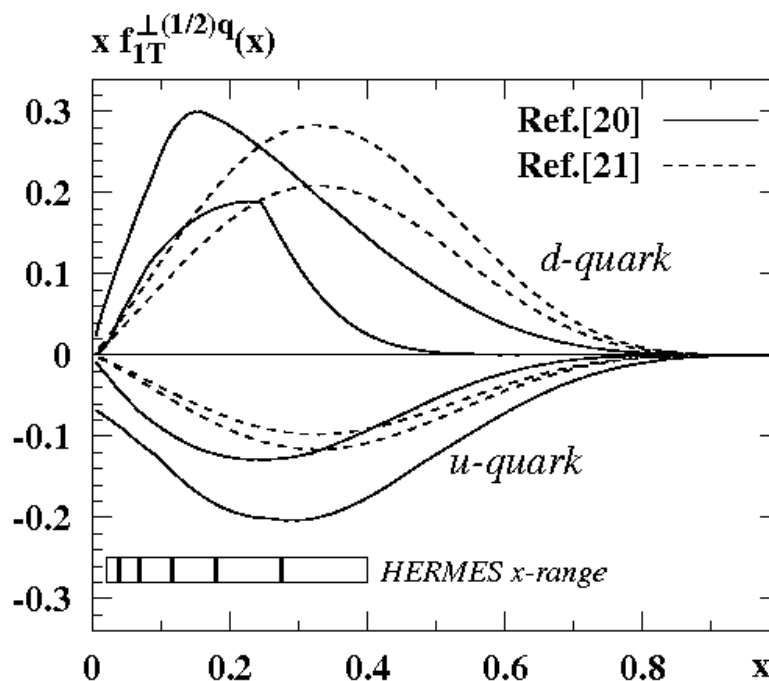
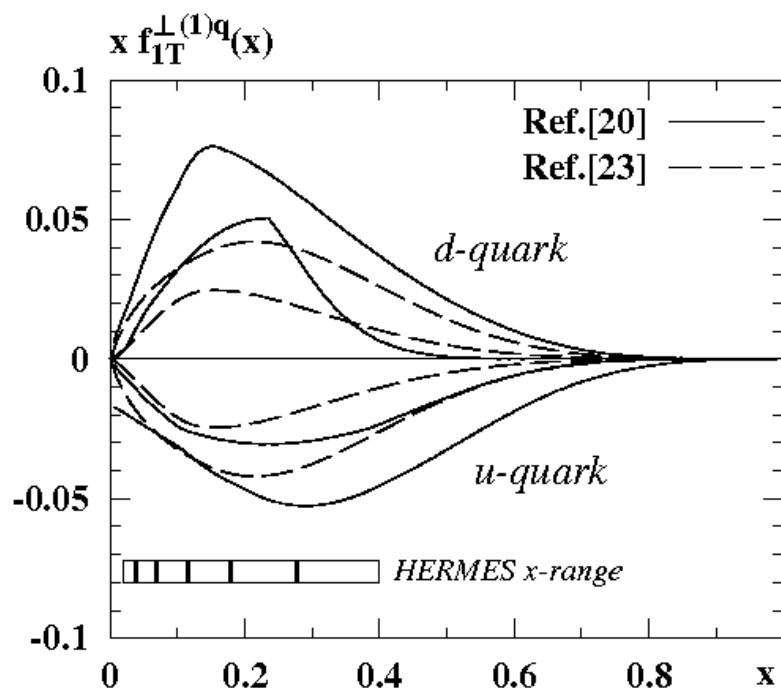
S_y

QCDSF coll. hep-lat/0612032

$$\vec{R}_\perp = \frac{\sum_i x_i \vec{r}_{i\perp}}{\sum_i x_i}$$

Diversi modelli per calcolare la funzione di Sivers, ma soprattutto nuove parametrizzazioni da analisi di dati di HERMES (dipendenti dal flavor), di BNL e di COMPASS

collezione di risultati in Anselmino *et al.* hep-ph/0511017



[20] Anselmino *et al.*, P.R. D72 (05) 094007

[21] Vogelsang, Yuan, P.R. D72 (05) 054028

[23] Collins *et al.*, hep-ph/0510342

Teorema di universalità per funzione di Sivers

Teorema di fattorizzazione

(Ji, Ma, Yuan, P.R. D71 (05) 034005;
Collins, Metz, P.R.L. **93** (04) 252001)

$$\frac{d^6\sigma_{OT}}{dx dy dz d\phi_S d\mathbf{P}_{h\perp}} = \frac{2\alpha^2}{sxy^2} \sum_{f\bar{f}} e_f^2 \left\{ \right.$$

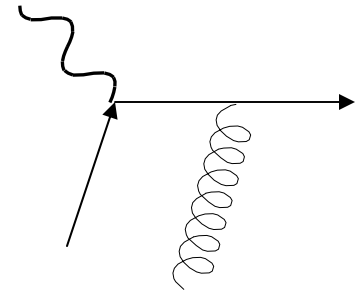
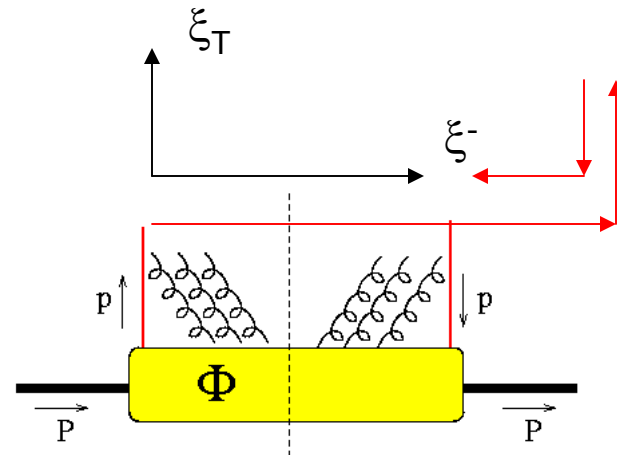
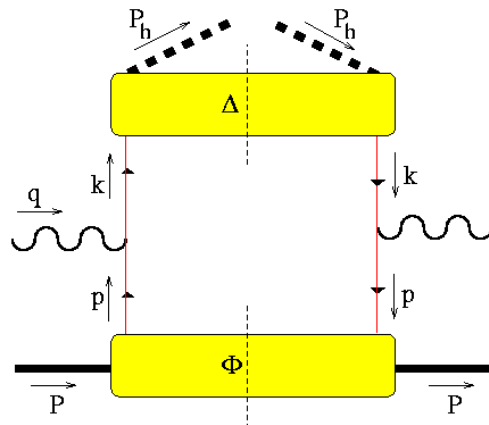
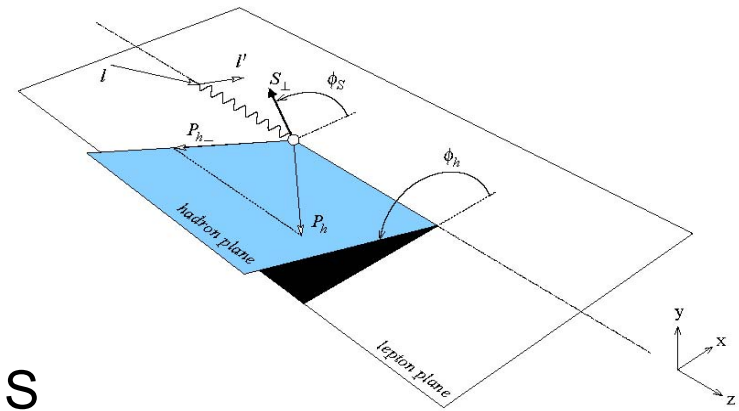
$$A(y) \mathcal{F} \left[f_1^f(x, \mathbf{p}_T^2) D_1^f(z, \mathbf{k}_T^2) \right]$$

$$+ \dots$$

$$- |\mathbf{S}_T| B(y) \sin(\phi_h - \phi_S) \mathcal{F} \left[\frac{\mathbf{p}_T \cdot \hat{\mathbf{P}}_{h\perp}}{M} f_{1T}^\perp(x, \mathbf{p}_T^2) D_1^f(z, \mathbf{k}_T^2) \right] + \dots \left. \right\}$$

SIDIS

$$e p^\uparrow \rightarrow e' \pi X$$



(continua)

Teorema di fattorizzazione

(Collins, Soper, Sterman, N.P. **B250** (85) 199)

$$\frac{d\sigma}{dx_1 dx_2 d\Omega d\mathbf{q}_T} = \frac{\alpha^2}{3Q^2} \sum_{f\bar{f}} e_f^2 \left\{ \right.$$



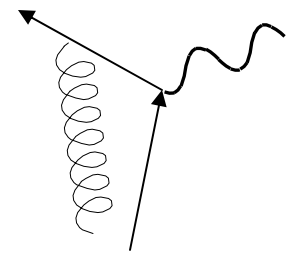
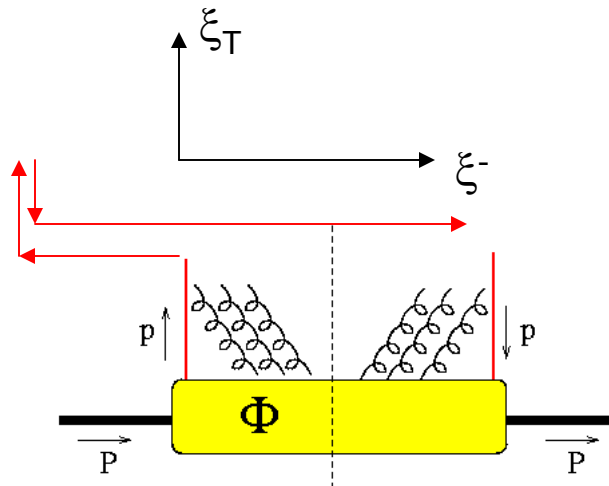
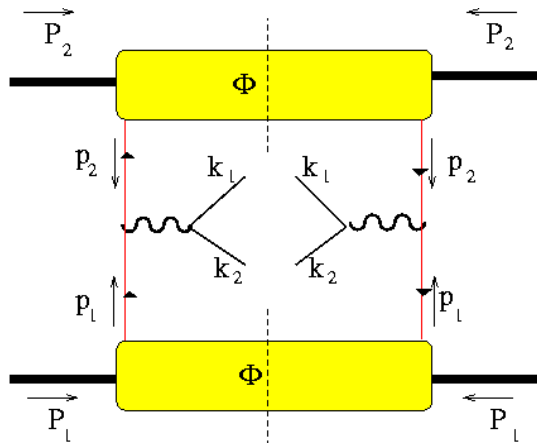
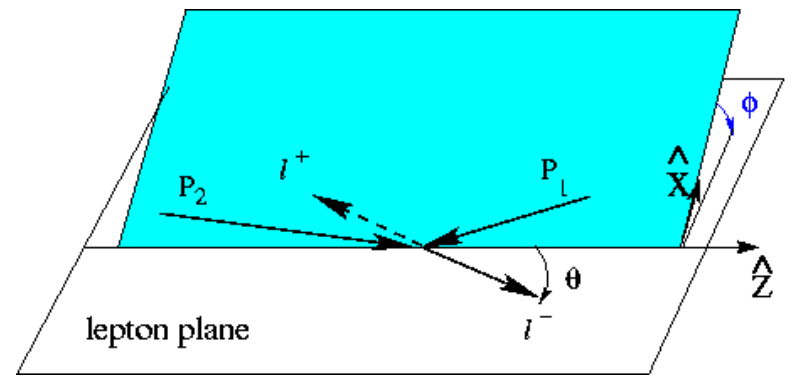
$$A(y) \mathcal{F} \left[f_1^f(x_1, \mathbf{p}_{1T}^2) \bar{f}_1^f(x_2, \mathbf{p}_{2T}^2) \right]$$

+.....

$$+ |\mathbf{S}_{1T}| A(y) \sin(\phi - \phi_{s1}) \mathcal{F} \left[\frac{\hat{\mathbf{h}} \cdot \mathbf{p}_{1T}}{M_1} f_{1T}^\perp(x_1, \mathbf{p}_{1T}^2) \bar{f}_1^f(x_2, \mathbf{p}_{2T}^2) \right] + \dots \left\{ \right.$$

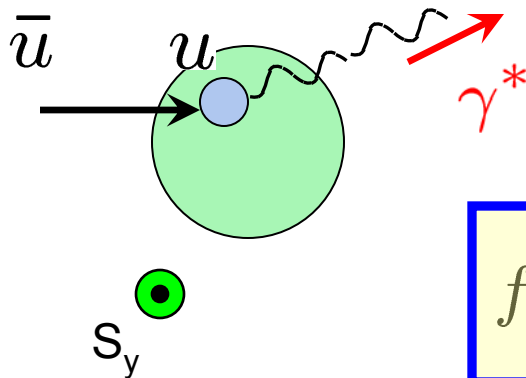
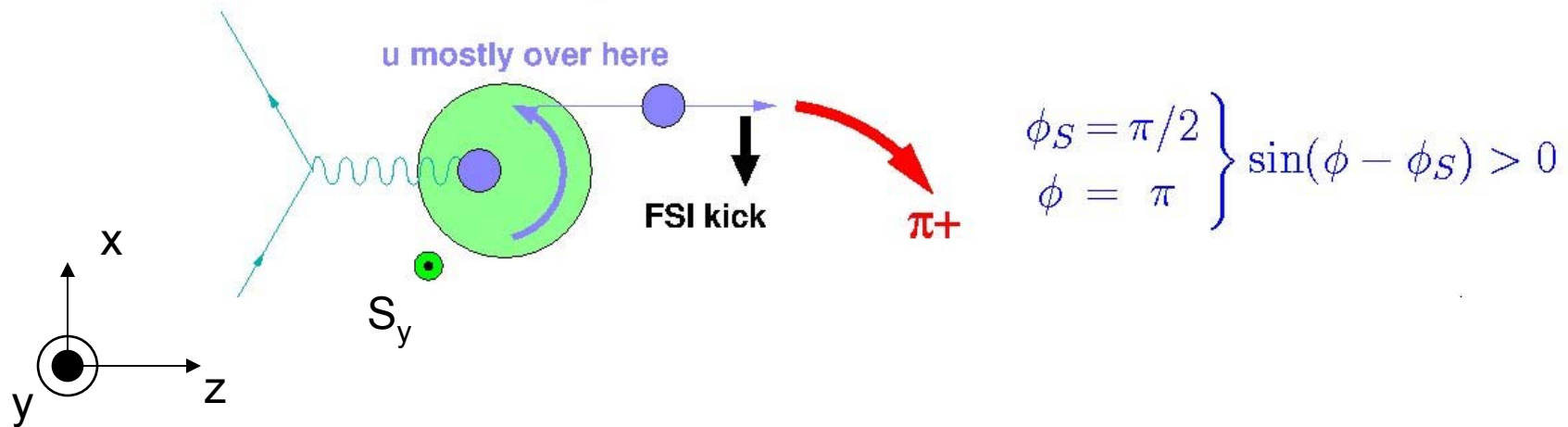
Drell-Yan

$$p p^\uparrow \rightarrow \mu^+ \mu^- X$$



cambio di segno !

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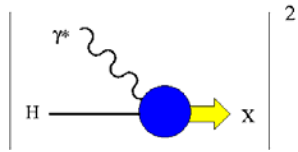
$$f_{1T}^{\perp q} \big|_{SIDIS} = -f_{1T}^{\perp q} \big|_{Drell-Yan}$$

STAR & PHENIX @ RHIC
 PAX @ GSI

conferma sperimentale ? Collins P.L. **B536** (02) 43

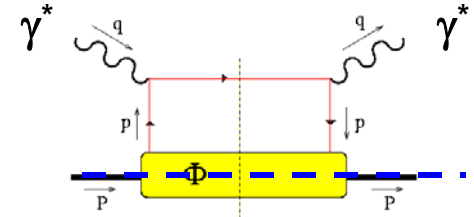
Generalized Parton Distributions (GPD)

DIS inclusivo teorema ottico forward Compton



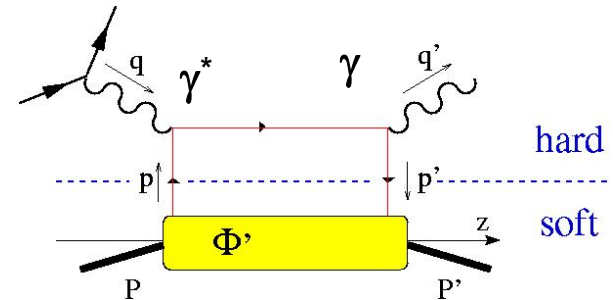
$$\sim \text{Im} \left\{ \begin{array}{c} \gamma^* \quad q \\ H \quad P \quad \text{blob} \quad P \quad H \\ \gamma^* \quad q \end{array} \right\} \quad Q^2 \rightarrow \infty \quad x_B \text{ fisso}$$

dominante



nonforward Compton

$$\begin{array}{c} \gamma^* \quad q \quad \gamma \quad q' \\ H \quad P \quad \text{blob} \quad P' \quad H' \end{array} \quad Q^2 \rightarrow \infty \quad x_B \text{ fisso} \quad t = (P-P')^2 \text{ piccolo}$$



Deeply Virtual Compton Scatt. (DVCS)

correlatore
diagonale

$$\Phi(p, P, S) = \int \frac{d^4 z}{(2\pi)^4} e^{ip \cdot z} \langle PS | \bar{\psi}(0) \psi(z) | PS \rangle$$



non
diagonale

$$\Phi'(\bar{p}, P, P', S', S) = \int \frac{d^4 z}{(2\pi)^4} e^{i\bar{p} \cdot z} \langle P' S' | \bar{\psi} \left(-\frac{z}{2} \right) \psi \left(\frac{z}{2} \right) | PS \rangle$$

$$\bar{p} = \frac{p + p'}{2}$$

teorema fattorizzazione
a twist 2 $\forall \alpha_s$

(Collins e Freund,
P.R.D59 ('99) 074009)

Cinematica del DVCS

$$\bar{P} = \frac{P + P'}{2} = (\bar{P}^0, 0, 0, \bar{P}^z) = (\bar{P}^+, \bar{P}^-, 0_\perp)$$

skewness $\xi = \frac{(P - P')^+}{(P + P')^+}$

$$P = \left((1 + \xi)\bar{P}^+, \frac{M^2 + \Delta_\perp^2/4}{2(1 + \xi)\bar{P}^+}, -\frac{\Delta_\perp}{2} \right)$$

$$P' = \left((1 - \xi)\bar{P}^+, \frac{M^2 + \Delta_\perp^2/4}{2(1 - \xi)\bar{P}^+}, +\frac{\Delta_\perp}{2} \right)$$

$$\Delta = P' - P = \left(-2\xi\bar{P}^+, \frac{\xi(M^2 + \Delta_\perp^2/4)}{(1 - \xi^2)\bar{P}^+}, \Delta_\perp \right)$$



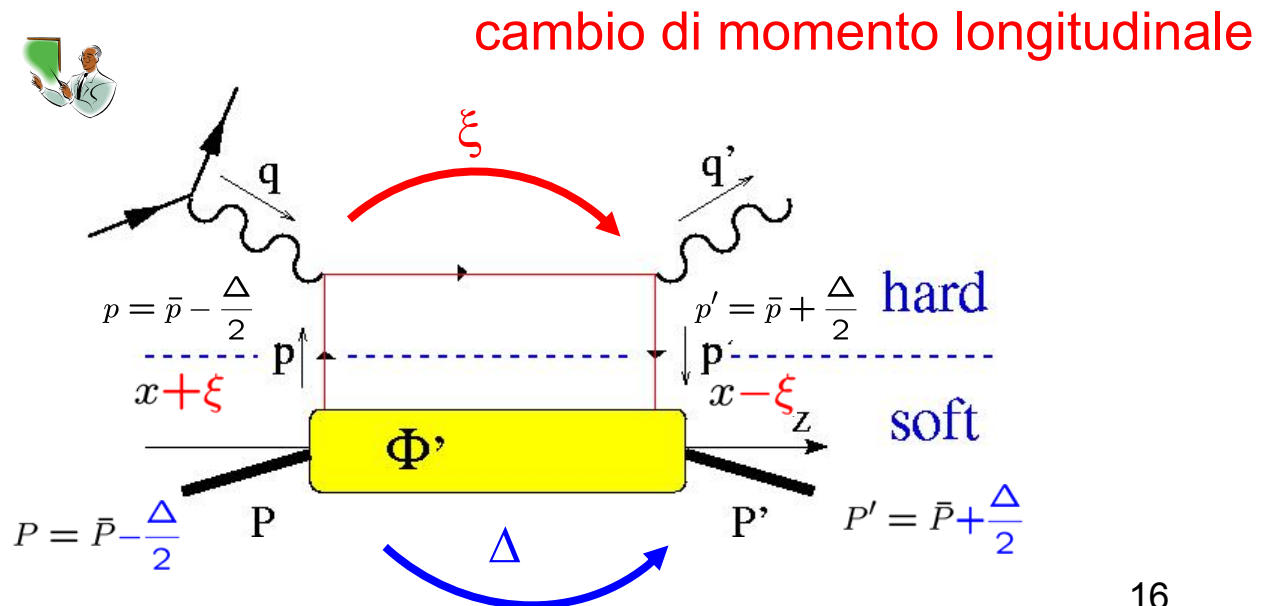
$$t = \Delta^2 = -\frac{4\xi^2 M^2 + \Delta_\perp^2}{1 - \xi^2}$$

dato $t \rightarrow \max \xi_t \leq -\frac{4\xi_t^2 M^2}{1 - \xi_t^2}$

$$\bar{p} = \frac{p + p'}{2} \quad x = \frac{\bar{p}^+}{\bar{P}^+}$$

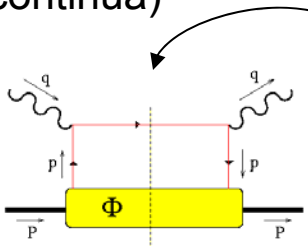
$$\frac{p^+}{\bar{P}^+} = x + \xi$$

$$\frac{p'^+}{\bar{P}^+} = x - \xi$$



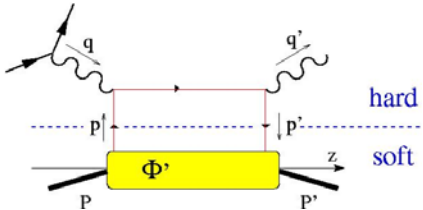
(continua)

regime DIS



regime DVCS

$$\begin{aligned}
 q^+ &= P'^+ - P^+ \\
 &= \Delta^+ \equiv -2\xi \bar{P}^+ \\
 \frac{x_B}{2 - x_B} &= \frac{-q^2}{4P \cdot q + q^2} \\
 &\sim \frac{-q^+}{2P^+ + q^+} = -\frac{q^+}{2\bar{P}^+} = \xi
 \end{aligned}$$



- interpretazione intuitiva della cinematica



$$1 \geq \xi \geq 0$$

$\frac{p^+}{\bar{P}^+} = x + \xi < 0$
 $\frac{p'^+}{\bar{P}^+} = x - \xi < 0$

antiquark

$\frac{p^+}{\bar{P}^+} = x + \xi > 0$
 $\frac{p'^+}{\bar{P}^+} = x - \xi < 0$

$q\bar{q}$

$\frac{p^+}{\bar{P}^+} = x + \xi > 0$
 $\frac{p'^+}{\bar{P}^+} = x - \xi > 0$

quark

Correlatore non locale → GPD

Invarianza per trasf. Lorentz, gauge + decomposizione di Gordon

$$\begin{aligned}\langle P' | J^\mu | P \rangle &\equiv \langle P' | \bar{q}(0) \gamma^\mu q(0) | P \rangle \\ &= \bar{u}(P') \gamma^\mu u(P) F_1(t) + \bar{u}(P') \frac{i\sigma^{\mu\nu} \Delta_\nu}{2M} u(P) F_2(t)\end{aligned}$$

caso diagonale : $t = \Delta^2 = (P' - P)^2$

$$\begin{aligned}\langle P | \bar{q}(0) \gamma \cdot n q(0) | P \rangle &= \bar{u}_P \gamma \cdot n u_P F_1(0) \\ &= \int dx \int \frac{d\lambda}{2\pi} e^{i\lambda \cdot x} \langle P | \bar{q}(0) \gamma \cdot n U_{[0,\lambda]} q(\lambda n) | P \rangle\end{aligned}$$

momentum sum rule $\equiv \bar{u}_P \gamma \cdot n u_P \int dx f_1(x) + \text{twist} > 2 \dots$ $n^\mu = (0, 1, 0_T)$

caso non diagonale

$$\langle P' | \bar{q}(0) \gamma \cdot n q(0) | P \rangle = \bar{u}_{P'} \gamma \cdot n u_P F_1(t) + \bar{u}_{P'} \frac{i\sigma^{\mu\nu} n_\mu \Delta_\nu}{2M} u_P F_2(t)$$

$$= \int dx \int \frac{d\lambda}{2\pi} e^{i\lambda \cdot x} \langle P' | \bar{q}(-\lambda n/2) \gamma \cdot n U_{[-\lambda/2, \lambda/2]} q(\lambda n/2) | P \rangle$$

$$\equiv \bar{u}_{P'} \gamma \cdot n u_P \int dx H(x, \xi, t) + \bar{u}_{P'} \frac{i\sigma^{\mu\nu} n_\mu \Delta_\nu}{2M} u_P \int dx E(x, \xi, t) + \dots$$

Commenti

- H,E funzioni di invarianti costruiti con $P^\mu, P'^\mu, n^\mu \rightarrow P \cdot n, P' \cdot n, t=(P'-P)^2 \equiv \Delta^2$
- boost lungo z modifica n^μ , ma H,E definite in modo invariante
- dipendenza da $P' \cdot n / P \cdot n \leftrightarrow \Delta \cdot n / \overline{P} \cdot n = -2 \xi$, oltre che da x,t
- Momentum sum rule

$$F_1(t) = \int dx H(x, \xi, t)$$

$$F_2(t) = \int dx E(x, \xi, t)$$

$\int dx$ cancella ogni riferimento a direzione “+” \rightarrow anche ξ
- limite diagonale (“forward”) : $t, \Delta \rightarrow 0$ $H(x,0,0) = f_1(x)$; E non determinata
- $f_1(x)$ da proiezione $\Phi^{[\gamma^+]}(p,P,S)$
- H, E da proiezione $\Phi'^{[\gamma^+]}(\overline{p},P,P',S,S')$
- analisi a twist=2 di Φ'

Analisi in twist del correlatore non diagonale

estrazione del contributo al leading twist procede come per PDF:

- proiezione delle componenti LC “good” con operatori γ^+ , $\gamma^+\gamma_5$, $i\sigma^{i+}\gamma_5$ integrando su direzione “-” soppressa



$$\begin{aligned}\Phi'[\gamma^+] &= \int \frac{dz^-}{2\pi} e^{ix\bar{P}^+z^-} \langle P'S' | \bar{\psi} \left(-\frac{z^-}{2} \right) \gamma^+ \psi \left(\frac{z^-}{2} \right) | PS \rangle \Big|_{z^+=z_\perp=0} \\ &= \frac{1}{\bar{P}^+} \bar{u}(P'S') \left\{ \gamma^+ H(x, \xi, t) + \frac{i\sigma^{+\nu}\Delta_\nu}{2M} E(x, \xi, t) \right\} u(PS)\end{aligned}$$

q non polarizzato
non helicity flip

$$\begin{aligned}\Phi'[\gamma^+\gamma_5] &= \int \frac{dz^-}{2\pi} e^{ix\bar{P}^+z^-} \langle P'S' | \bar{\psi} \left(-\frac{z^-}{2} \right) \gamma^+\gamma_5 \psi \left(\frac{z^-}{2} \right) | PS \rangle \Big|_{z^+=z_\perp=0} \\ &= \frac{1}{\bar{P}^+} \bar{u}(P'S') \left\{ \gamma^+\gamma_5 \tilde{H}(x, \xi, t) + \frac{\gamma_5\Delta^+}{2M} \tilde{E}(x, \xi, t) \right\} u(PS)\end{aligned}$$

q polarizzato long.
non helicity flip

$$\begin{aligned}\Phi'[i\sigma^{i+}\gamma_5] &= \int \frac{dz^-}{2\pi} e^{ix\bar{P}^+z^-} \langle P'S' | \bar{\psi} \left(-\frac{z^-}{2} \right) i\sigma^{i+}\gamma_5 \psi \left(\frac{z^-}{2} \right) | PS \rangle \Big|_{z^+=z_\perp=0} \\ &= \frac{i}{\bar{P}^+} \bar{u}(P'S') \left\{ \sigma^{i+}\gamma_5 H_T(x, \xi, t) + \frac{\epsilon^{i+\alpha\beta}\Delta_\alpha\bar{P}_\beta}{M^2} \tilde{H}_T(x, \xi, t) \right. \\ &\quad \left. + \frac{\epsilon^{i+\alpha\beta}\Delta_\alpha\gamma_\beta}{2M} E_T(x, \xi, t) + \frac{\epsilon^{i+\alpha\beta}\bar{P}_\alpha\gamma_\beta}{M} \tilde{E}_T(x, \xi, t) \right\} u(PS)\end{aligned}$$

helicity flip