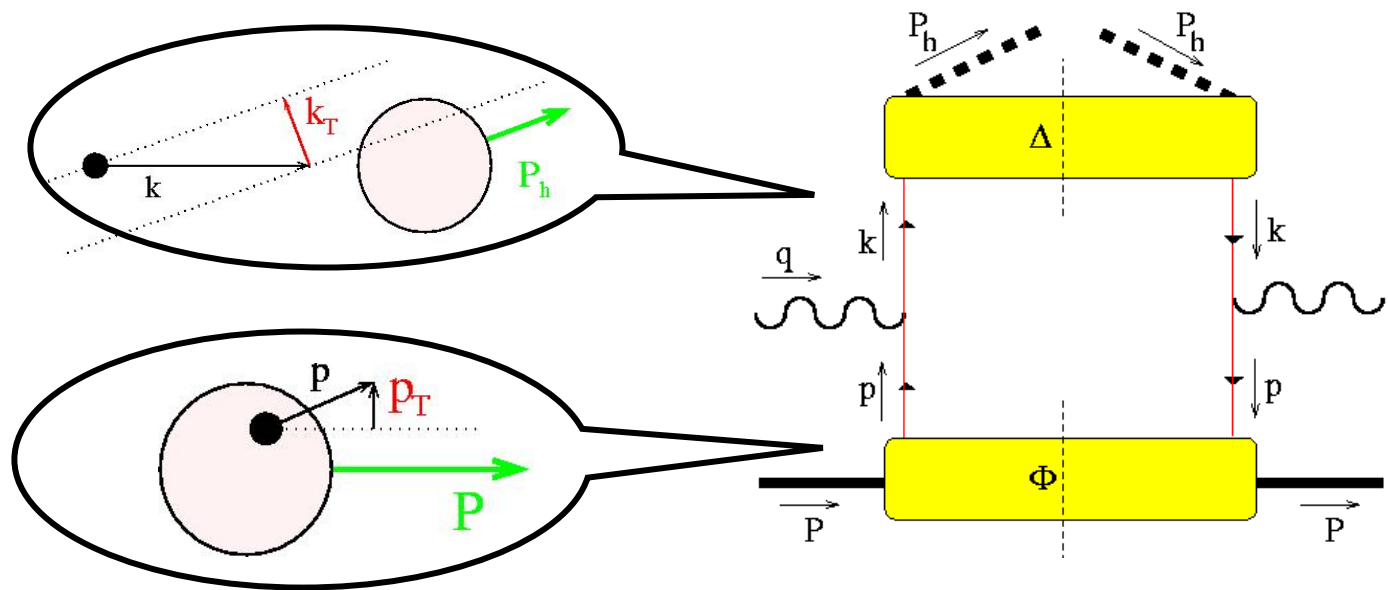


Riassunto della lezione precedente

- proprietà peculiari della trasversità; evoluzione tipica di PDF si non-singoletto
- formalismo di elicità e disequaglianza di Soffer
- estrazione di h_1 dai dati :
 - Drell-Yan polarizzato; SSA piccola; possibilità di usare antiprotoni
 - SIDIS \rightarrow funzioni di frammentazione (FF)
 - necessità di strutture naïve T-odd per avere partner chiral-odd
 - necessità di considerare adroni finali polarizzati per avere contributo al leading twist
 - SSA con Λ^\uparrow ; ma meccanismo ignoto

- **osservazione** : in SIDIS $\{P, q, P_h\}$ non sono tutti collineari; nel T-frame, se la sezione d'urto è differenziale anche in $d\mathbf{q}_T$
 → sensibilità ai momenti trasversi dei partoni nel vertice hard
 → struttura più ricca

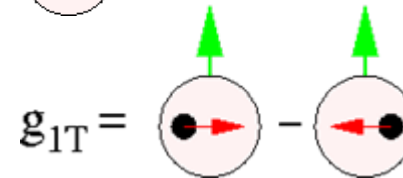
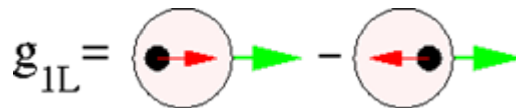
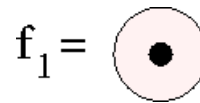


PDF dipendenti da momento trasverso intrinseco

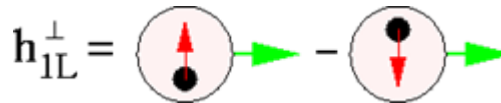
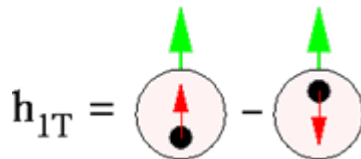
$$\Phi^{[\Gamma]}(x, \mathbf{p}_T, S) = \int dp^- \text{Tr} [\Phi(p, P, S) \Gamma] \Big|_{p^+ = xP^+}$$

Proiezioni al leading twist

$$\Phi^{[\gamma^+]}(x, \mathbf{p}_T, S) = f_1(x, \mathbf{p}_T^2)$$



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



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

Proiezioni al twist 3 :
lista ancora più lunga

twist 2

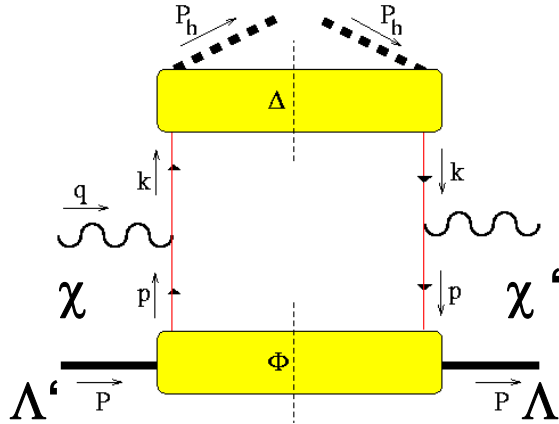
q^\uparrow

$N \rightarrow$

pesata con \mathbf{p}_T



Rappresentazione di elicità di $\Phi(x, \mathbf{p}_T, S)$



PDF	chiral-even	chiral-odd
$N \rightarrow = L$	g_{1L}	h_{1L}^\perp
$N^\uparrow = T$	g_{1T}	h_1, h_{1T}^\perp

$$\Phi_{\chi'\chi}^{\Lambda'\Lambda} = \begin{pmatrix} \text{RR} & \text{RL} \\ \text{LR} & \text{LL} \end{pmatrix}$$

$\begin{pmatrix} f_1 + g_{1L} & \frac{ \vec{p}_T }{M} e^{-i\phi_p} g_{1T} \\ \frac{ \vec{p}_T }{M} e^{i\phi_p} g_{1T} & f_1 - g_{1L} \end{pmatrix}$	$\begin{pmatrix} \frac{ \vec{p}_T }{M} e^{i\phi_p} h_{1L}^\perp & \frac{ \vec{p}_T ^2}{M^2} e^{2i\phi_p} h_{1T}^\perp \\ 2h_1 & -\frac{ \vec{p}_T }{M} e^{i\phi_p} h_{1L}^\perp \end{pmatrix}$
$\begin{pmatrix} \frac{ \vec{p}_T }{M} e^{-i\phi_p} h_{1L}^\perp & 2h_1 \\ \frac{ \vec{p}_T ^2}{M^2} e^{-2i\phi_p} h_{1T}^\perp & -\frac{ \vec{p}_T }{M} e^{-i\phi_p} h_{1L}^\perp \end{pmatrix}$	$\begin{pmatrix} f_1 - g_{1L} & -\frac{ \vec{p}_T }{M} e^{-i\phi_p} g_{1T} \\ -\frac{ \vec{p}_T }{M} e^{i\phi_p} g_{1T} & f_1 + g_{1L} \end{pmatrix}$

$h_1 = h_{1T} + h_{1T}^\perp \frac{\vec{p}_T^2}{M^2}$

FF dipendenti da momento trasverso intrinseco

$$\Delta^{[\Gamma]}(z, \mathbf{k}_T, S_h) = \frac{1}{4z} \int dk^+ \text{Tr} [\Delta(k, P_h, S_h) \Gamma] \Big|_{k^- = P_h^- / z}$$

Proiezioni al leading twist

$$D_1 = \bullet \longrightarrow \bigcirc$$

$$\Delta^{[\gamma^-]}(z, \mathbf{k}_T, S_h) = D_1(z, \mathbf{k}_T^2) + \frac{(\mathbf{k}_T \times \mathbf{S}_{hT})_i}{M_h} D_{1T}^\perp(z, \mathbf{k}_T^2)$$

$$G_{1L} = \left(\bullet \xrightarrow{\text{red}} \bigcirc \xrightarrow{\text{green}} \right) - \left(\bullet \xleftarrow{\text{red}} \bigcirc \xrightarrow{\text{green}} \right) \quad G_{1T} = \left(\bullet \xrightarrow{\text{red}} \bigcirc \uparrow_{\text{green}} \right) - \left(\bullet \xleftarrow{\text{red}} \bigcirc \uparrow_{\text{green}} \right)$$

$$\Delta^{[\gamma^- \gamma_5]}(z, \mathbf{k}_T, S_h) = \lambda_h G_{1L}(z, \mathbf{k}_T^2) + \frac{\mathbf{k}_T \cdot \mathbf{S}_{hT}}{M_h} G_{1T}^\perp(z, \mathbf{k}_T^2)$$

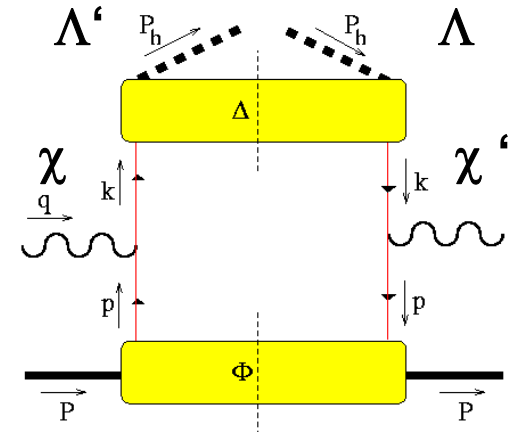
$$H_{1T} = \left(\uparrow_{\text{red}} \bullet \longrightarrow \bigcirc \uparrow_{\text{green}} \right) - \left(\downarrow_{\text{red}} \bullet \longrightarrow \bigcirc \uparrow_{\text{green}} \right)$$

$$\Delta^{[i\sigma^{i-} \gamma_5]}(z, \mathbf{k}_T, S_h) = S_{hT}^i H_{1T}(z, \mathbf{k}_T^2) + \frac{(\hat{\mathbf{n}}_T \times \mathbf{k}_T)_i}{M_h} H_{1T}^\perp(z, \mathbf{k}_T^2)$$

$$+ \frac{k_T^i}{M_h} \left[\lambda_h H_{1L}^\perp(z, \mathbf{k}_T^2) + \frac{\mathbf{k}_T \cdot \mathbf{S}_{hT}}{M_h} H_{1T}^\perp(z, \mathbf{k}_T^2) \right]$$

$$H_{1L}^\perp = \left(\uparrow_{\text{red}} \bullet \longrightarrow \bigcirc \xrightarrow{\text{green}} \right) - \left(\downarrow_{\text{red}} \bullet \longrightarrow \bigcirc \xrightarrow{\text{green}} \right) \quad H_{1T}^\perp = \left(\uparrow_{\text{red}} \bullet \longrightarrow \bigcirc \nearrow_{\text{green}} \right) - \left(\downarrow_{\text{red}} \bullet \longrightarrow \bigcirc \nearrow_{\text{green}} \right)$$

Rappresentazione di elicità di $\Delta(z, \mathbf{k}_T, S_h)$



PFF	chiral even		chiral-odd
	q non pol.	$q \rightarrow$	$q \uparrow$
H non pol.	D_1		H_1^\perp
$H \rightarrow = L$		G_{1L}	H_{1L}^\perp
$H \uparrow = T$	D_{1T}^\perp	G_{1T}	H_{1T}, H_{1T}^\perp

solo per D_1 c'è parametrizzazione da dati sperimentali di $e^+e^- \rightarrow h X$!

naïve T-even

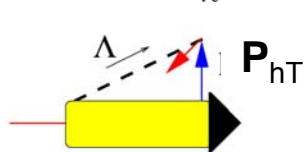
naïve T-odd

(continua)

D_{1T}^\perp e H_1^\perp sono FF su cui il time-reversal non impone condizioni; se le interazioni residue (FSI) tra adrone e jet nello stato finale si annullano
 → entrambe le FF = 0

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

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



$p N \rightarrow \Lambda^\uparrow X$
 Heller et al., P.R.L. **41** ('78) 607

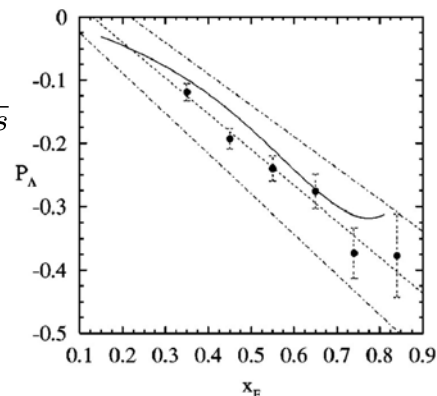
grandi SSA $\propto d\sigma(\Lambda^\uparrow) - d\sigma(\Lambda^\downarrow)$
 possibile spiegazione?

$$D_{1T}^\perp = \left(\bullet \rightarrow \text{circle with green arrow} - \bullet \rightarrow \text{circle with green arrow} \right)$$

$$P_\Lambda(x_F)$$

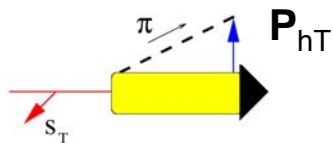
$$x_F = x_1 - x_2$$

$$\simeq 2(p_\Lambda)_L / \sqrt{s}$$



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

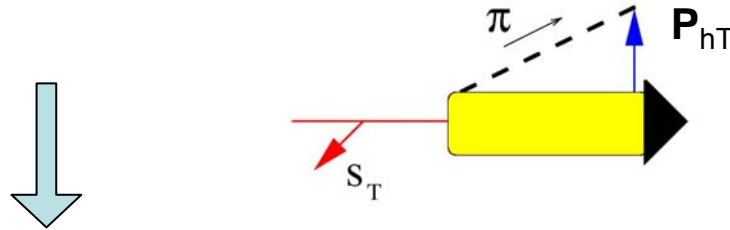
$$H_1^{\perp q}(z, \mathbf{P}_{hT}^2) 2 \frac{\hat{\mathbf{k}} \times \mathbf{P}_{hT} \cdot \mathbf{S}_q}{zM_h} = D(h/q^\uparrow) - D(h/q^\downarrow)$$



$$H_1^\perp = \left(\text{circle with red arrow} \rightarrow \bullet - \text{circle with red arrow} \rightarrow \bullet \right)$$

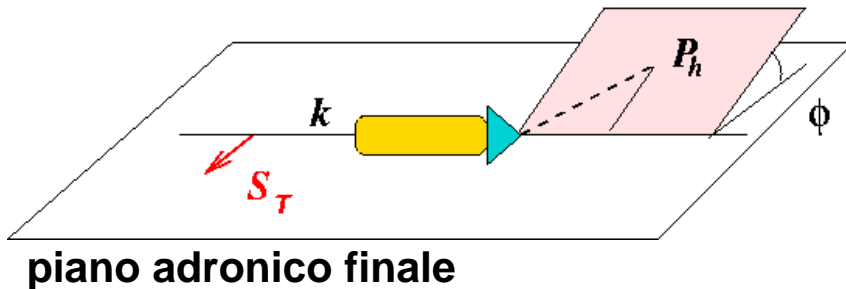
entrambe legano lo spin di un oggetto alla dipendenza da \mathbf{P}_{hT} di un altro oggetto non polarizzato

(continua)



effetto Collins (Collins, Nucl.Phys. **B396** ('93) 161) :

trasferire polarizzazione trasversa del quark di frammentazione non alla polarizz. trasversa dell'adrone, ma al moto orbitale di un adrone non polarizzato \rightarrow SSA dipendente da $\mathbf{P}_{h\perp}$



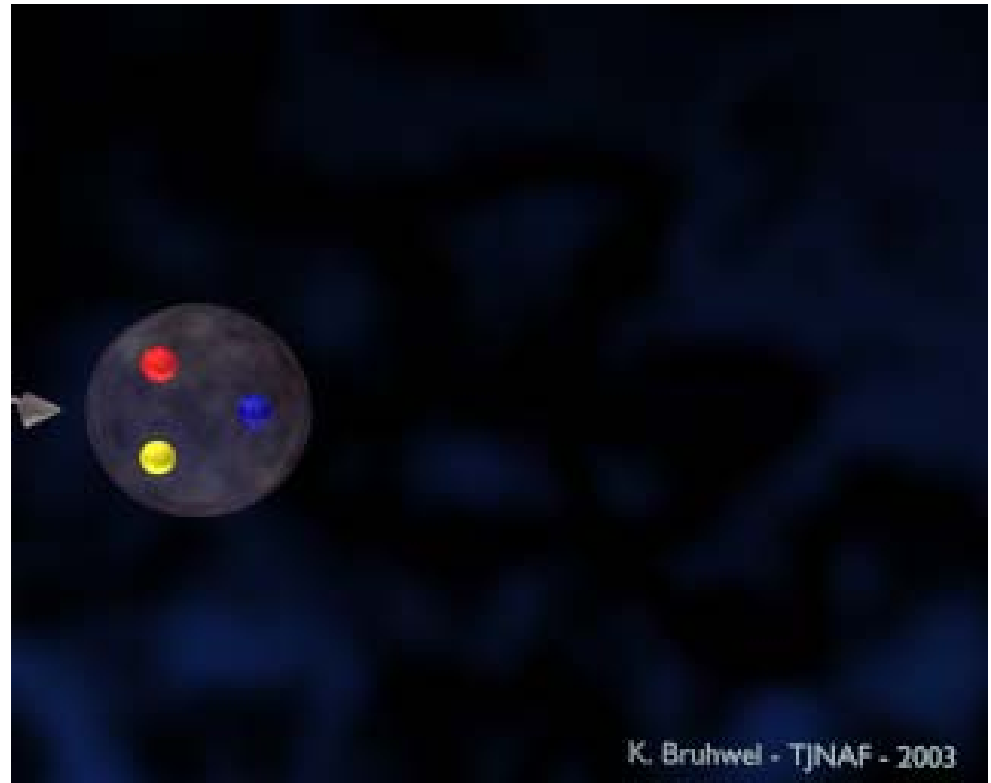
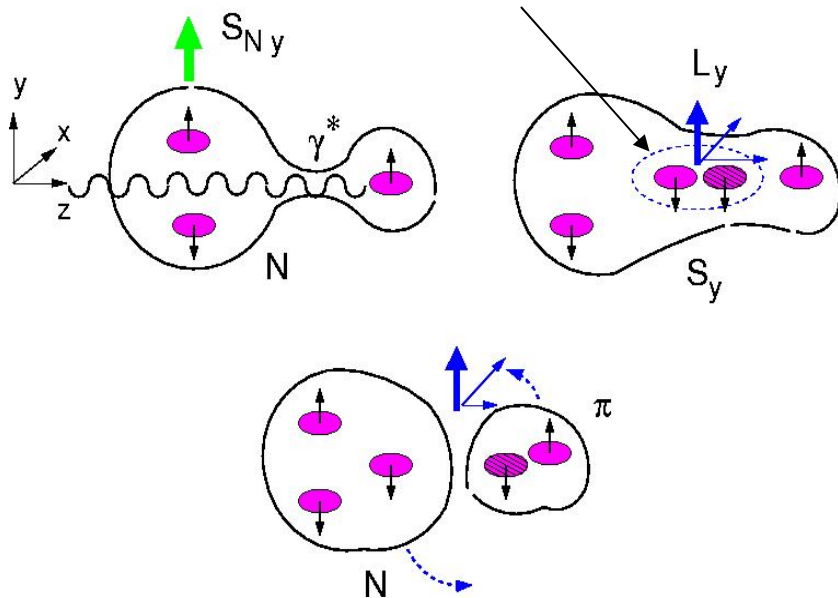
asimmetria in

$$\sin \phi \propto k \times P_h \cdot S_T$$

tipico effetto non perturbativo
(legato al momento angolare
orbitale dei partoni)

Congettura semi-classica : poichè γ^* colpisce $q^\uparrow \rightarrow$ la stringa di forza di colore tra q^\uparrow e il diquark (qq) ha un momento angolare orbitale; quando la stringa si rompe, la coppia quark-antiquark porta momento angolare orbitale e determina l'asimmetria azimutale nell'emissione dell'adrone finale osservato (Artru , hep-ph/9310323)

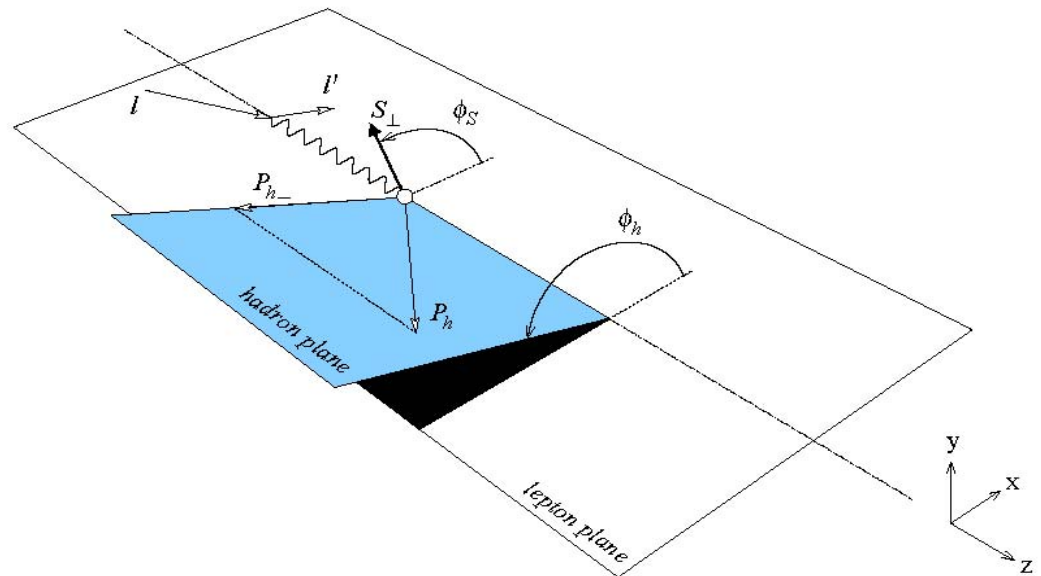
quantici vuoto $J^{PC} = 0^{++}$
 quarkonio ha $S=1 \rightarrow 2S+1L_J = 3P_0$



K. Bruhwieler - TJNAF - 2003

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

per avere l'effetto Collins
bisogna mantenere
la sez. d'urto
differenziale in $\mathbf{P}_{h\perp}$



$$\frac{d^6 \sigma_{OT}}{dx dy dz d\phi_S d\mathbf{P}_{h\perp}} = \frac{2\alpha^2}{sxy^2} \sum_{f,\bar{f}} e_f^2 \left\{ A(y) \mathcal{F} \left[f_1^f(x, \mathbf{p}_T^2) D_1^f(z, \mathbf{k}_T^2) \right] \right. \\ \left. + |\mathbf{S}_T| B(y) \underbrace{\sin(\phi_h + \phi_S)}_{\phi_C} \mathcal{F} \left[\frac{\mathbf{k}_T \cdot \hat{\mathbf{P}}_{h\perp}}{M_h} h_1^f(x, \mathbf{p}_T^2) H_1^{\perp f}(z, \mathbf{k}_T^2) \right] \right\}$$

ϕ_C angolo di Collins

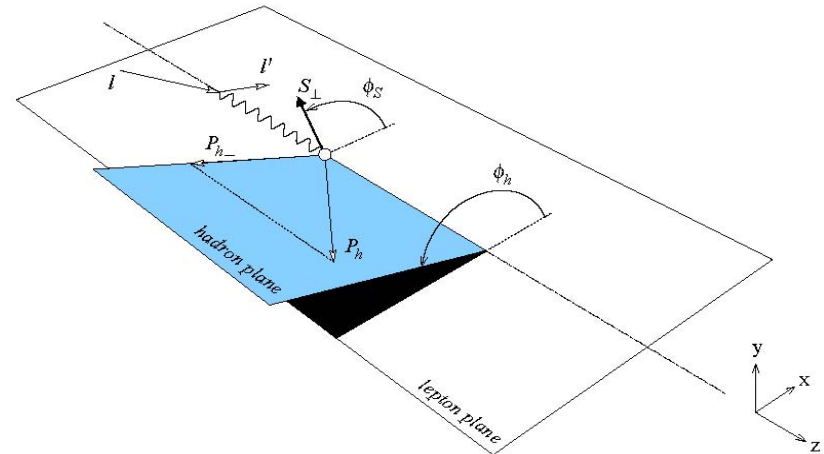
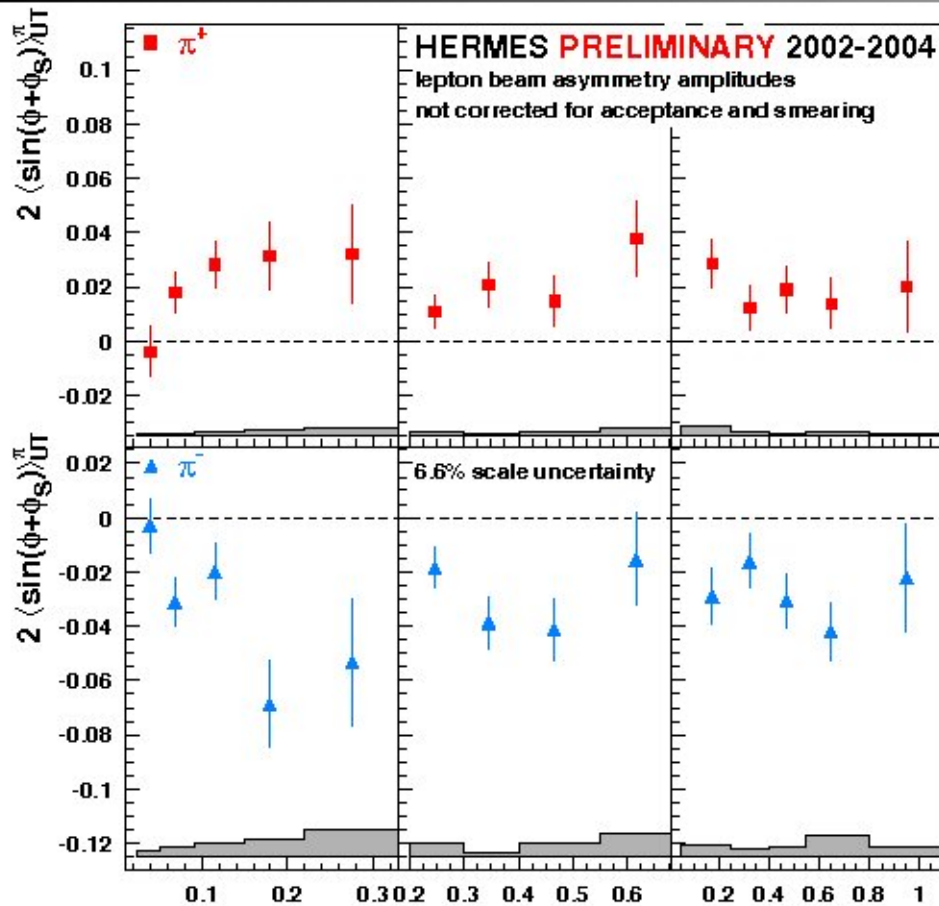
$$H_1^{\perp(1)}(z) = \int d\mathbf{k}_T \frac{\mathbf{k}_T^2}{2M_h} H_1^{\perp}(z, \mathbf{k}_T)$$

SSA

$$\frac{\int d\phi_S d\mathbf{P}_{h\perp} \frac{|\mathbf{P}_{h\perp}|}{M_h} \sin \phi_C (d\sigma^\uparrow - d\sigma^\downarrow)}{\int d\phi_S d\mathbf{P}_{h\perp} (d\sigma^\uparrow + d\sigma^\downarrow)} \propto |\mathbf{S}_T| \frac{B(y)}{A(y)} \frac{\sum_{f\bar{f}} e_f^2 z h_1^f(x) H_1^{\perp f(1)}(z)}{\sum_{f\bar{f}} e_f^2 f_1^f(x) D_1^f(z)}$$

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

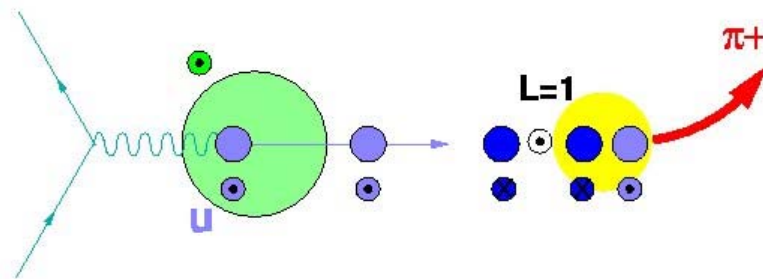
Airapetian *et al.*, HERMES
P.R.L. **94** (05) 012002



assumendo $h_1^u > 0$

$$N^\uparrow = p^\uparrow = \{u^\uparrow d^\downarrow u^\uparrow\}$$

$$\vec{k}(\parallel \hat{z}) \times \vec{P}_h(\parallel \hat{x}) \cdot \vec{S}_T(\parallel \hat{y}) \rightarrow \sin \phi_C > 0$$



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



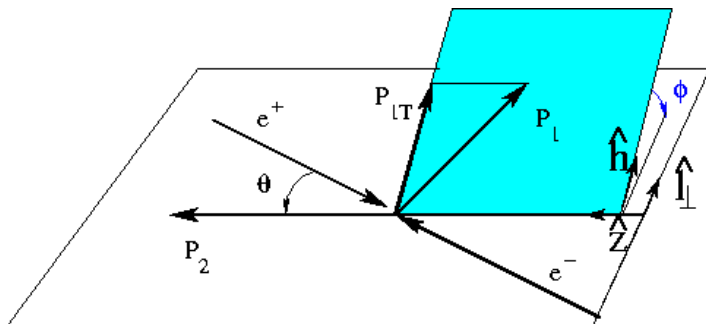
Trasversità e funzione di Collins

incognita h_1 estraibile attraverso nuova incognita H_1^\perp ;
 come avere informazioni su H_1^\perp ?

Ji, Ma, Yuan P.R. D71 (04); P.L. B597 (04)
 Collins, Metz P.R.L. 93 (04)

1. dimostrazione di fattorizzazione per SIDIS con funzioni non integrate in \mathbf{p}_T
2. ipotesi di universalità di PDF e PFF (dimostrazione valida solo a twist 2)
3. estrazione di PFF (funzione di Collins H_1^\perp) da $e^+e^- \rightarrow \pi^+\pi^- X$

consideriamo $e^+e^- \rightarrow \pi^+\pi^- X$

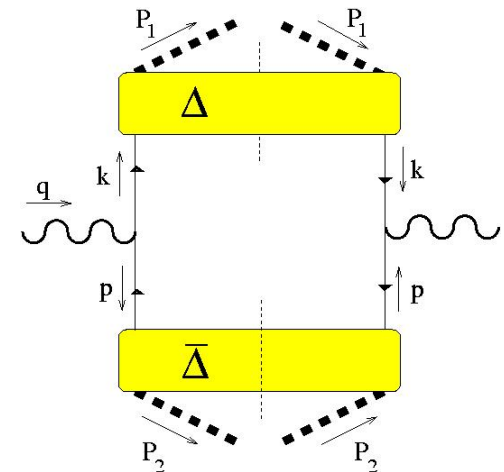


piano scattering

leading twist

$$z_1 = \frac{P_{h1}^-}{k_1^-}$$

$$z_2 = \frac{P_{h2}^+}{k_2^+}$$

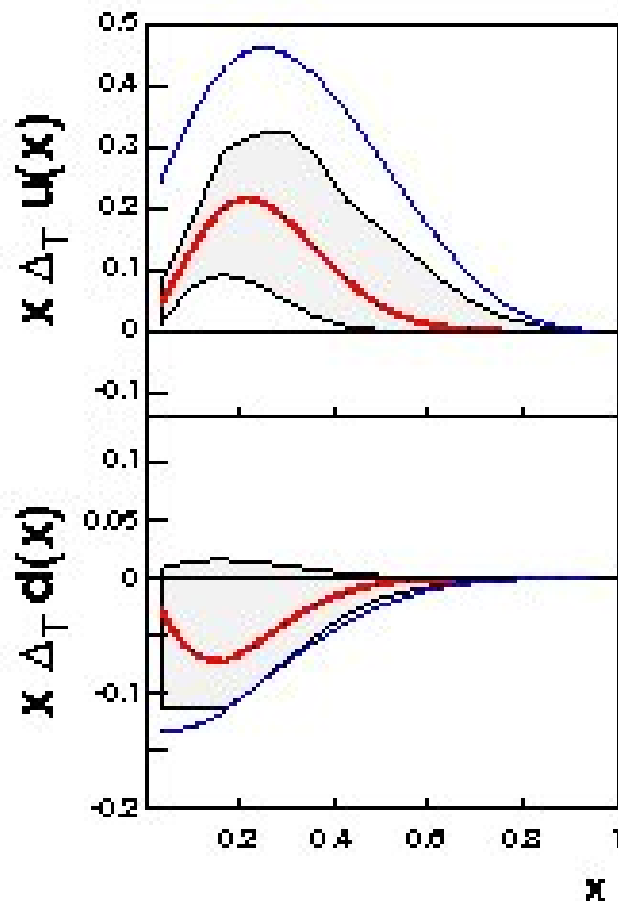


$$\frac{\int d\phi d\mathbf{q}_T \mathbf{q}_T^2 \cos 2\phi \frac{d\sigma}{d\Omega dz_1 dz_2 d\mathbf{q}_T}}{\int d\phi d\mathbf{q}_T \frac{d\sigma}{d\Omega dz_1 dz_2 d\mathbf{q}_T}} = \frac{2 \sin^2 \theta}{1 + \cos^2 \theta} \frac{\sum_{f\bar{f}} e_f^2 H_1^{\perp f(1)}(z_1) \bar{H}_1^{\perp f(1)}(z_2) + (1 \leftrightarrow 2)}{\sum_{f\bar{f}} e_f^2 D_1^f(z_1) \bar{D}_1^f(z_2) + (1 \leftrightarrow 2)}$$

nessuna misura di polarizzazione necessaria !

(continua)

1. fit di dati da esperimento e^+e^- a BELLE (Giappone)
2. estrazione di $H_1^{\perp(1)q}(z)$ per $q=u,d$
3. fit di dati HERMES e COMPASS per SSA in SIDIS
4. estrazione di trasversità h_1^q per $q=u,d$



banda grigia = incertezza teorica
linea rossa = valore più probabile
linea blu = Soffer bound

Anselmino et al.
P.R. D75 (07) 054032

Dipendenza da momento trasverso intrinseco

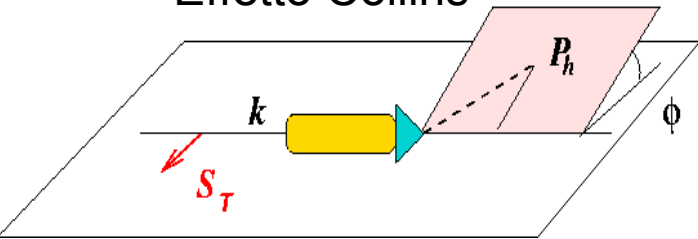
- per processi dove PDF e FF dipendono esplicitamente da momento trasverso intrinseco dei partoni, teorema di fattorizzazione dimostrato per:
 - Drell-Yan e e^+e^- (Collins, Soper, Sterman, N.P. **B250** (85) 199)
 - SIDIS solo a twist=2 per $P_{h\perp} \sim Q$ (Ji, Ma, Yuan, P.L. **B597** (04) 299;)→ evoluzione delle PDF, delle FF e della relativa SSA non sono legate
- inoltre nel calcolo delle correzioni radiative → cancellazione tra contributi di gluoni soft reali e gluoni virtuali (fattorizzazione collineare) non succede → “rottura della fattorizzazione collineare”

calcolo implica $\propto \int_{|P_{h\perp}|}^{Q^2}$ → diluizione della SSA per $|P_{h\perp}| \ll Q^2$

⇒ cercare SSA generata da partner chiral-odd di h_1 ma indipendente da momento intrinseco dei partoni

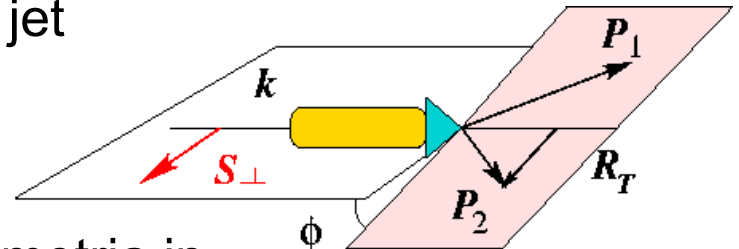
Dihadron fragmentation functions

Effetto Collins



$$\int d\mathbf{P}_{hT} \dots \mathbf{k} \times \mathbf{P}_{hT} \cdot \mathbf{S}_q \dots \rightarrow 0$$

SSA con due adroni leading (non polarizzati) nello stesso jet



asimmetria in

$$\sin \phi \propto \mathbf{P}_1 \times \mathbf{P}_2 \cdot \mathbf{S}_T = \mathbf{P}_h \times \mathbf{R} \cdot \mathbf{S}_T$$

(Collins et al., N.P.**B420**('94)565 ;
Jaffe, Jin, Tang, P.R.L.**80**('98)1166 ;
poi sviluppato in modo sistematico qui a Pavia)

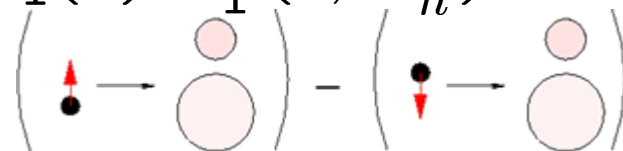
$$\begin{aligned} \mathbf{P}_h &= \mathbf{P}_1 + \mathbf{P}_2 \\ \mathbf{R} &= \frac{1}{2} (\mathbf{P}_1 - \mathbf{P}_2) \end{aligned}$$

$\int d\mathbf{P}_{h\perp} \rightarrow$ SSA in $\phi \equiv \phi_R \rightarrow$ fattorizzazione collineare (non c'è "diluizione" per fattori di forma di Sudakov)

equazioni di evoluzione note a LL [Ceccopieri, Radici, Bacchetta, P.L. **B650** (07) 81]

sez. d'urto $e^+e^- \rightarrow (\pi^+\pi^-)(\pi^+\pi^-)$ X esprimibile in forma fattorizzata
 \rightarrow segnale più "pulito"

SSA generata dalla combinazione $h_1(x) H_1^{\nabla}(z, M_h^2)$



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

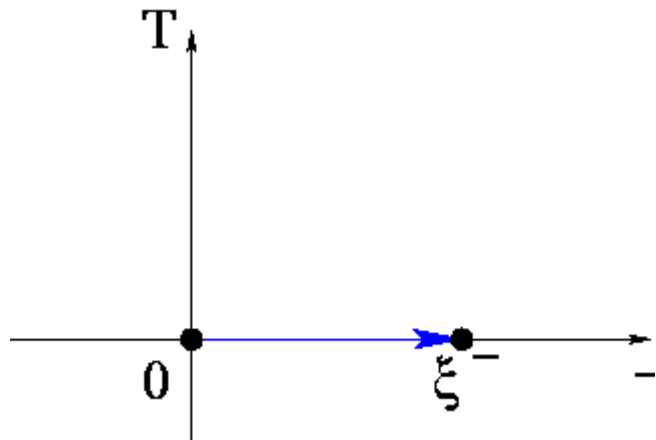
$$\Phi(x, S) = \int \frac{d^4 \xi}{2\pi} e^{-ixP^+ \xi^-} \langle P, S | \underbrace{\bar{\psi}(\xi^-) \psi(0)}_{\text{campi di quark a punti 4-dim. diversi}} | P, S \rangle \Big|_{\xi^+, \xi_\perp = 0}$$

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) $\rightarrow \text{twist 3} \dots$

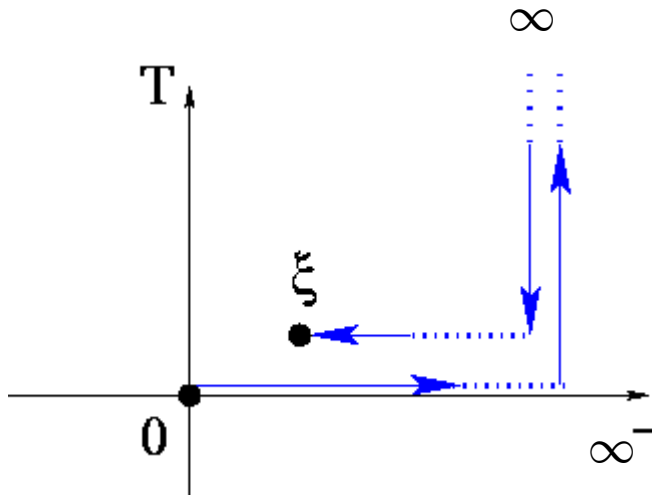
$A^+ = 0$ gauge \rightarrow def. precedente

(continua)

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

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

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



analisi in twist rivela che al twist 2
contribuiscono sia A^+ ,
che \mathbf{A}_T a $n_- = \infty$

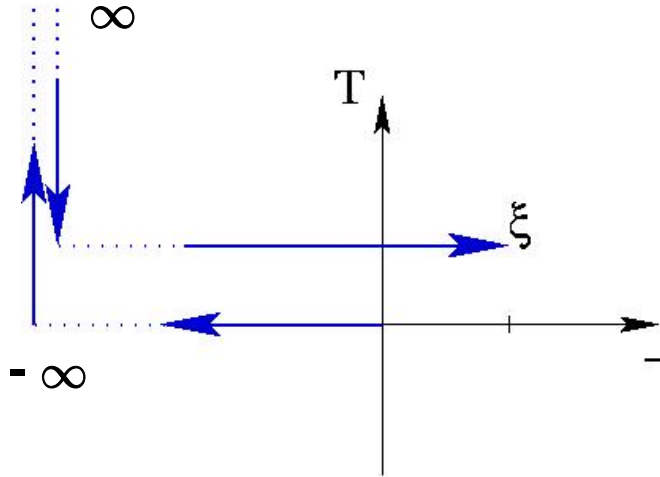
eliminabile in
axial gauge $A^+ = 0$

non eliminabile!

(continua)

analogamente

$$\Delta(z, \mathbf{k}_T) \rightarrow \dots \psi(\xi) | \dots \rangle \langle \dots | \bar{\psi}(0) \dots \rightarrow \dots U_{[-\infty^-, \xi^-]} U_{[\infty^T, \xi^T]} \bar{\psi}(\xi) | \dots \rangle \langle \dots | \bar{\psi}(0) \left(U_{[0, -\infty^-]} U_{[0, \infty^T]} \right)^\dagger \dots$$



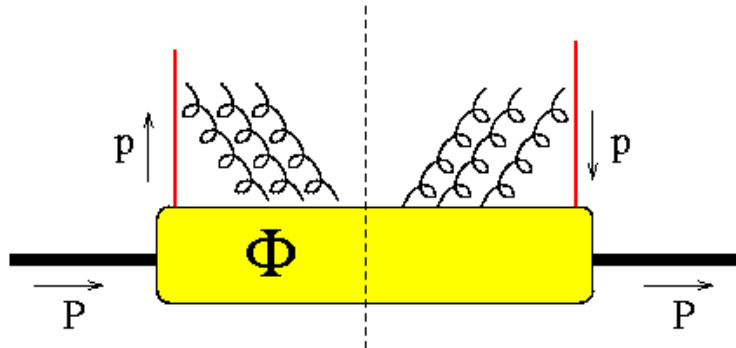
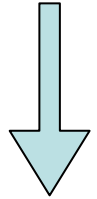
preserva interpretazione probabilistica
al twist 2 anche se strutture T-odd sono
gia` presenti

(continua)

Φ invariante per trasformazioni di $SU_c(3)$

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

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



“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)

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

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

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

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

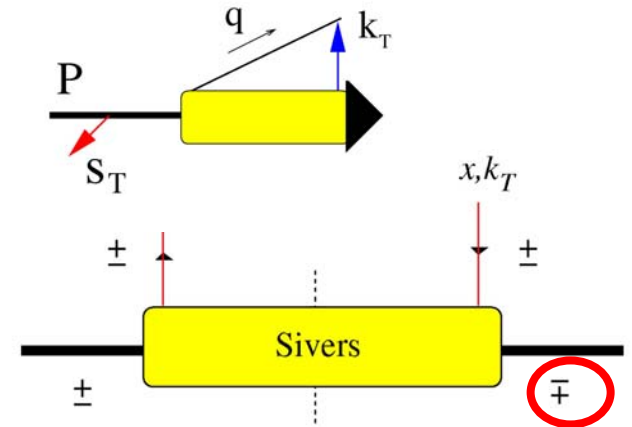
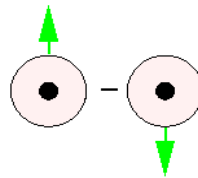
$$\int d\mathbf{p}_T \text{ (T-odd) } = 0$$

(continua)

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

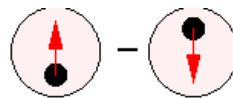
$$-f_{1T}^{\perp q}(x, \mathbf{k}_T^2) 2 \frac{\hat{\mathbf{P}} \times \mathbf{k}_T \cdot \mathbf{S}}{M} = f(q/p^\uparrow) - f(q/p^\downarrow)$$

funzione di Sivers

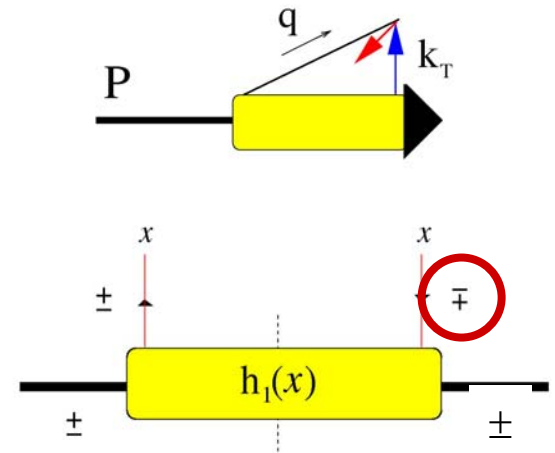


$$f(q^\uparrow/p) = \frac{1}{2} \left(f_1^q(x, \mathbf{k}_T^2) - h_1^{\perp q}(x, \mathbf{k}_T^2) \frac{\hat{\mathbf{P}} \times \mathbf{k}_T \cdot \mathbf{S}_q}{M} \right)$$

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



funzione di Boer-Mulders

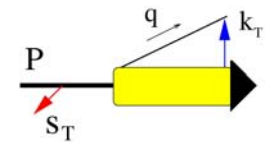


(continua)

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}

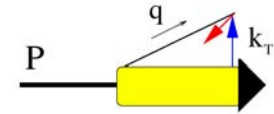
Sivers

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



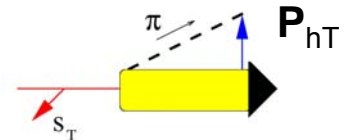
Boer-Mulders

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



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

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

