Pavia 3-4 Apr. 2007

Funzioni di frammentazione in due adroni

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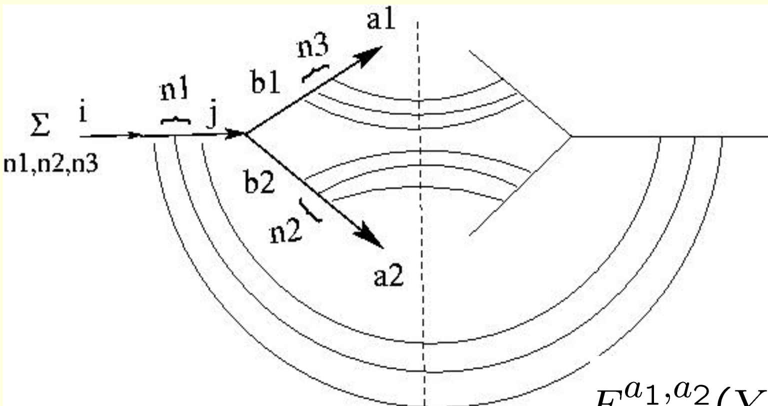
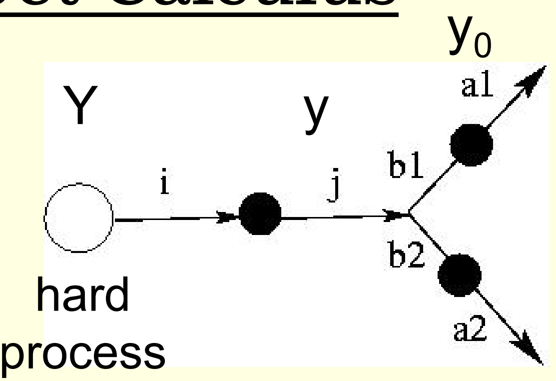
Outline

1. Introduzione: OPE $\rightarrow$ I.P.M. $\rightarrow$ approccio diagrammatico
   $\longrightarrow$ teoremi di fattorizzazione
2. Frammentazione in 1 adrone: stato dell'arte per e+e- $\rightarrow$ h + X;
   $\rightarrow$ sviluppo in N^nLO, N^mLL, $1/Q^{t-2}$
3. Introduzione alle regole del Jet Calculus
4. Frammentazione in 2 adroni: e+e- $\rightarrow h_1\, h_2 + X$ a NLO, LL, t=2
   $\rightarrow$ Di-hadron Fragmentation Functions (DiFF) $\rightarrow$ extended DiFF
5. DiFF polarizzate: analisi in twist; spin analyzer della polarizz. partonica; Single Spin Asymmetry (SSA)
6. Fenomenologia delle SSA: modelli di DiFF; confronto con dati sperimentali preliminari da HERMES (DESY) e COMPASS (CERN)

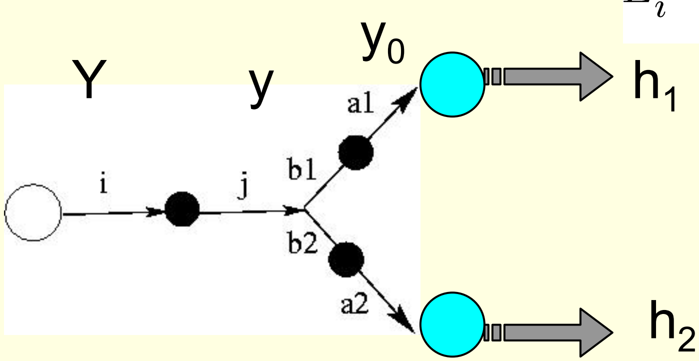
Frammentazione in due adroni in Jet Calculus



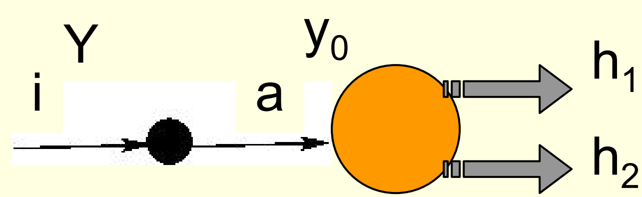
$\equiv E_i^{a1,a2}$



$$E_i^{a_1,a_2}(Y) = \int_{y_0}^{Y} dy\, E_{b_1}^{a_1}(y) \otimes E_{b_2}^{a_2}(y) \otimes \hat{P}_{b_1 b_2}^{j} \otimes E_i^{j}(Y-y)$$



+



$$D^{i\to h_1 h_2}(z_1, z_2, Y) = E_i^{a_1,a_2}(Y) \otimes D^{a_1\to h_1}(z_1, y_0) \otimes D^{a_2\to h_2}(z_2, y_0) \quad + E_i^{a}(Y-y_0) \otimes \boxed{D^{a\to h_1 h_2}(z_1, z_2, y_0)}$$

1. Jet Calculus
2. **Frammentazione in 2 adroni**
3. 2h SIDIS

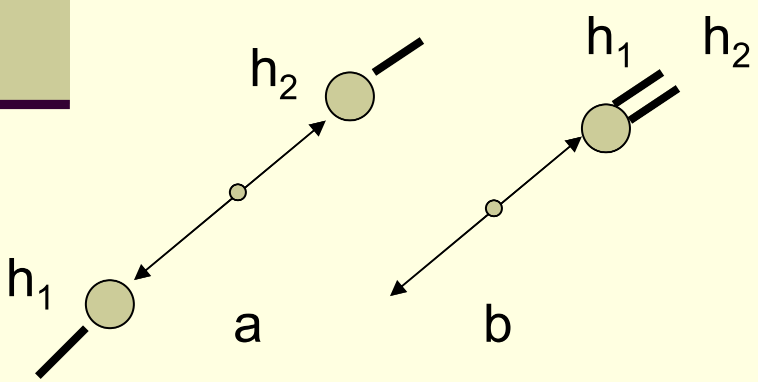
1. **e+e- $\rightarrow$ h_1 h_2 + X a NLO**
2. DiFF
3. extDiFF

Di-hadron Fragmentation Functions (DiFF) e spazio fasi per la frammentazione in due adroni

$$
\begin{aligned}
D^{i\to h_1 h_2}(z_1,z_2,Y) &= E_i^{a_1,a_2}(Y)\otimes D^{a_1\to h_1}(z_1,y_0)\otimes D^{a_2\to h_2}(z_2,y_0) \\
&\quad + E_i^{a}(Y-y_0)\otimes D^{a\to h_1 h_2}(z_1,z_2,y_0)
\end{aligned}
$$

$$
\begin{aligned}
\frac{d}{dY}D^{i\to h_1 h_2}(z_1,z_2,Y) &= D^{k\to h_1}(z_1,Y)\otimes D^{l\to h_2}(z_2,Y)\otimes \hat{P}^{i}_{kl} \\
&\quad + D^{k\to h_1 h_2}(z_1,z_2,Y)\otimes P_{ki}
\end{aligned}
$$

A
B



	a	b
$O(\alpha_s^0)$	A	B
$O(\alpha_s)$	A	A+B

1. Jet Calculus
2. **Frammentazione in 2 adroni**
3. 2h SIDIS

1. **e+e- $\rightarrow$ h_1 h_2 + X a NLO**
2. DiFF
3. extDiFF

A,B indistinguibili in zona kin. b a NLO O(α_s)

$$
\begin{aligned}
d\sigma^{NLO} &= \sum_{ij} d\hat{\sigma}_{ij}^{NLO} \otimes D^{i\to h_1} \otimes D^{j\to h_2} + \sum_i d\hat{\sigma}_i^{NLO} \otimes D^{i\to h_1 h_2} \\
&= \sum_{i,j} \left[d\hat{\sigma}_{q\bar{q}}^{(0)} + \frac{\alpha_s}{2\pi} \left(d\hat{\sigma}_{ij}^{(1)} + f_{ij} \right) \right] \otimes D^{i\to h_1} \otimes D^{j\to h_2} \\
&\quad + \sum_{i\neq j} \frac{\alpha_s}{2\pi} d\bar{\hat{\sigma}}_{ij}^{(1)} \otimes D^{i\to h_1} \otimes D^{j\to h_2} \\
&\quad + \sum_i \left[d\hat{\sigma}_q^{(0)} + \frac{\alpha_s}{2\pi} \left(d\hat{\sigma}_i^{(1)} + f_i \right) \right] \otimes D^{i\to h_1 h_2}
\end{aligned}
$$

$$
\begin{aligned}
D_{i\to h}^{NLO} &= \sum_j D_{j\to h} \otimes \left[d\hat{\sigma}_{q\bar{q}}^{(0)} + \frac{\alpha_s}{2\pi} d\hat{\sigma}_{ij}^{(1)} \right] \\
D_{i\to h_1 h_2}^{NLO} &= D_{i\to h_1 h_2} \otimes \left[d\hat{\sigma}_q^{(0)} + \frac{\alpha_s}{2\pi} d\hat{\sigma}_i^{(1)} \right] \\
&\quad + \sum_{j\neq i} D_{i\to h_1} \otimes D_{j\to h_2} \otimes \frac{\alpha_s}{2\pi} d\bar{\hat{\sigma}}_{ij}^{(1)}
\end{aligned}
$$

<u>DiFF sono necessarie per cancellare singolarità</u> quando 2 adroni prodotti da frammentazione di due partoni collineari

de Florian e Vanni, P.L. **B578** (04) 139

1. Jet Calculus
2. **Frammentazione in 2 adroni**
3. 2h SIDIS

1. **e+e- $\rightarrow$ h_1 h_2 + X a NLO**
2. DiFF
3. extDiFF

Ma dati sperimentali sono spesso DiFF (M_h)

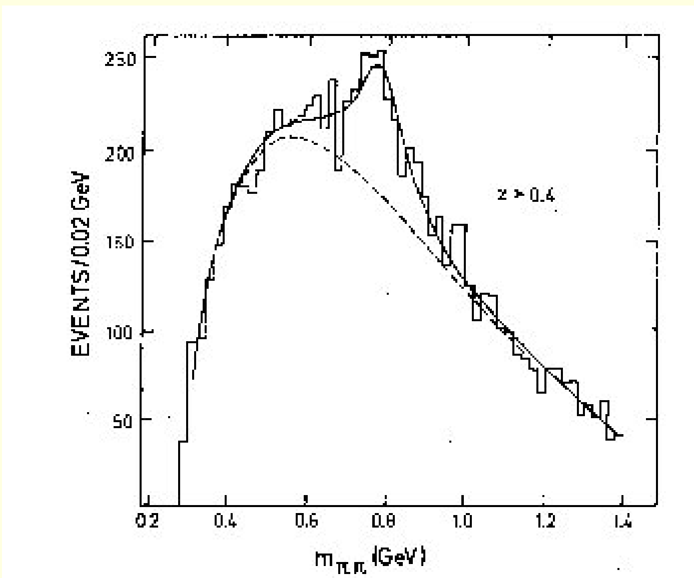


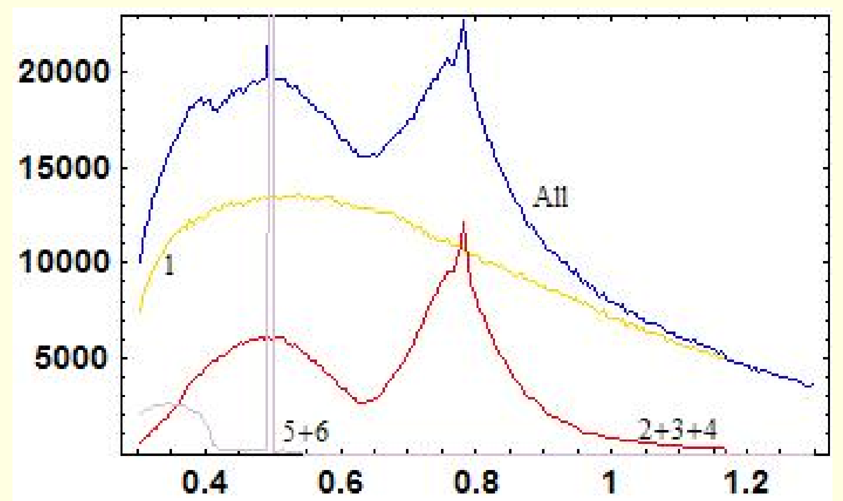
FIG. 5. $\pi^+\pi^-$ mass distribution after removal of the elastic events. The curves were determined by the fitting procedure described in the text.

ep $\rightarrow$ e' ρ^0 + X   no eventi elastici

Cohen et al., P.R. D25 (82) 634

E_e=11.5 GeV   1<Q^2<6 GeV^2

z>0.4   2.8<W<4.2 GeV

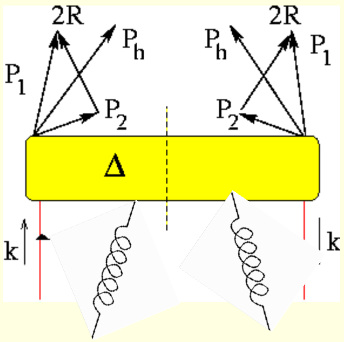


ep$^\uparrow$ $\rightarrow$ e' ($\pi^+\pi^-$) X   PYTHIA output a kin. HERMES

Q^2 > 1 GeV^2 0.023<x<0.4 W^2 >4 GeV^2 no eventi elastici e diffrattivi

1. Jet Calculus
2. **Frammentazione in 2 adroni**
3. 2h SIDIS

1. e+e- → $h_1\, h_2$ + X a NLO
2. **DiFF**
3. extDiFF



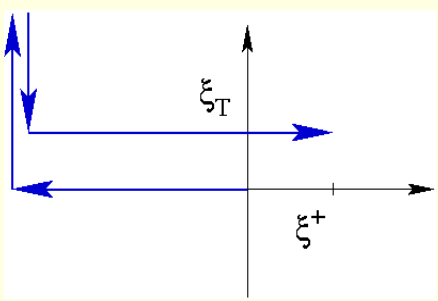
correlatore quark-quark non locale

$$
\begin{aligned}
\Delta(k,P_h,R) &= \sum_X \int \frac{d^4\xi}{(2\pi)^4}\frac{d^4P_X}{(2\pi)^4}\, e^{ik\cdot\xi}\, \langle 0|\psi(\xi)|P_1,P_2,X\rangle\langle P_1,P_2,X|\overline{\psi}(0)|0\rangle \\
&= C_1 M_h + C_2\, \not{P}_h + C_3\, \not{R} + C_4\, \not{k} + \frac{C_5}{M_h}\sigma_{\mu\nu}P_h^\mu k^\nu + \frac{C_6}{M_h}\sigma_{\mu\nu}R^\mu k^\nu \\
&\quad + \frac{C_7}{M_h}\sigma_{\mu\nu}P_h^\mu R^\nu + \frac{C_8}{M_h^2}\gamma_5\epsilon_{\mu\nu\rho\sigma}\gamma^\mu P_h^\nu R^\rho k^\sigma
\end{aligned}
$$

hermitianità + inv. parità; inv. T-rev. → $C_{5\text{-}8} = 0$

Bianconi *et al*, P.R. D**62** (00) 034008

inserendo A_T, A^- → color-gauge inv. fino a t=3



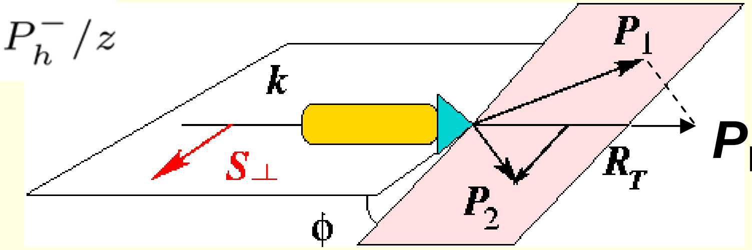
$$
\begin{aligned}
\Delta(\vec{k}_T,P_h,R) &= \int dk^+\, \Delta(k,P_h,R)\Big|_{k^-=P_h^-/z} \\
&= \sum_X \int \frac{d\xi^+ d\vec{\xi}_T}{(2\pi)^3}\frac{d^4P_X}{(2\pi)^4}\, e^{ik\cdot\xi}\, \langle 0|U^T_{[\infty,\xi]}U^+_{[-\infty,\xi]}\,\psi(\xi)|P_1,P_2,X\rangle \\
&\quad \times \langle P_1,P_2,X|\overline{\psi}(0)\,U^+_{[0,-\infty]}U^T_{[0,\infty]}|0\rangle\,\Big|_{\xi^-=0}
\end{aligned}
$$

ma analisi in twist inalterata: proiezioni a t=2 definite semi-positive

1. Jet Calculus
2. **Frammentazione in 2 adroni**
3. 2h SIDIS

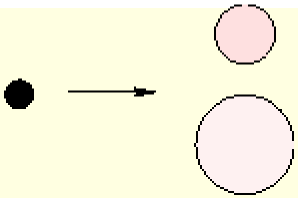
1. e+e- $\to h_1\, h_2 + X$ a NLO
2. **DiFF**
3. extDiFF

$$\Delta^{[\Gamma]} = \frac{1}{4z}\int dk^+ \,\mathrm{Tr}\left[\Gamma\Delta(k,P_h,R)\right]\Big|_{k^-=P_h^-/z}$$



t=2

$$\Delta^{[\gamma^-]} = D_1 =$$



$$\Delta^{[\Gamma]}(z,\zeta,\mathbf{k}_T^2,\mathbf{R}_T^2,\mathbf{k}_T\cdot\mathbf{R}_T)$$
$$\equiv \Delta^{[\Gamma]}(z,\zeta,M_h^2,\phi,\mathbf{k}_T^2)$$

$$R^2 = \frac{M_1^2+M_2^2}{2} - \frac{M_h^2}{4}$$

$$\boxed{R_T^2 = \frac{1}{2}\left[\frac{(1-\zeta)(1+\zeta)}{2}M_h^2 - (1-\zeta)M_1^2 - (1+\zeta)M_2^2\right]}$$

$$P_h\cdot R = \frac{M_1^2-M_2^2}{2}$$

$$P_h\cdot k = \frac{M_h^2}{2z} + z\,\frac{k^2+|\mathbf{k}_T|^2}{2}$$

$$R\cdot k = \frac{(M_1^2-M_2^2)-\frac{\zeta}{2}M_h^2}{2z} + z\zeta\,\frac{k^2+|\mathbf{k}_T|^2}{4} - \mathbf{k}_T\cdot\mathbf{R}_T$$

$$\boxed{\begin{aligned} k^- &= \frac{P_h^-}{z} \equiv \frac{P_h^-}{z_1+z_2} \\ \zeta &= \frac{2R^-}{P_h^-} \equiv \frac{z_1-z_2}{z} \end{aligned}}$$

t=3

$$\Delta^{[1]} = E$$

$$\Delta^{[\gamma^i]} = \left\{ \begin{array}{l} \dfrac{\epsilon_T^{ij}R_T^j}{M_h}\, D^{\sphericalangle\,\prime} \\[2ex] \dfrac{\epsilon_T^{ij}k_T^j}{M_h}\, D^{\perp} \end{array}\right.$$

qgq

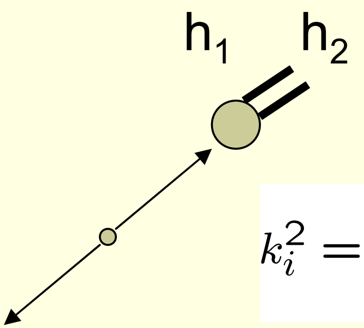
$$\Delta_A^i \to \frac{M_h}{2zQ}\left\{\frac{R_T^i}{M_h}\tilde{D}^{\sphericalangle} - \frac{\gamma^i}{2}\tilde{E}\right\}$$

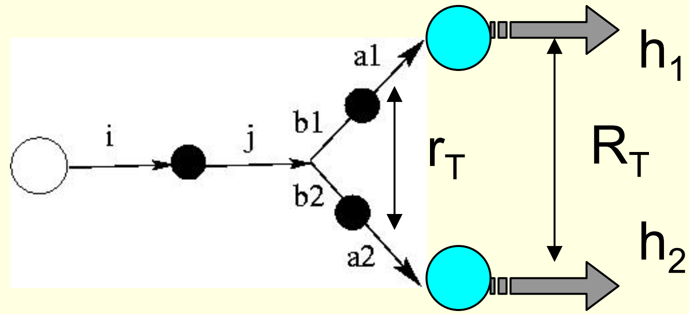
$$\begin{aligned}\tilde{D}^{\sphericalangle} &= D^{\sphericalangle} - zD_1^{(1)} \\ \tilde{E} &= E - z\frac{m}{M_h}D_1\end{aligned}$$

Bacchetta e Radici,
P.R. D**69** (04) 074026

Frammentazione in 2 adroni ~ collineari con dipendenza da M_h

selezioniamo kin. b

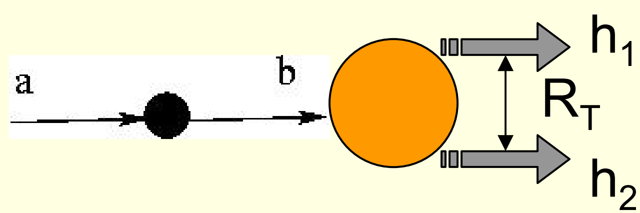




termine A
R_T "semi-hard"

$$k_i^2 = \frac{k_{a_1}^2}{u} + \frac{k_{a_2}^2}{1-u} + \frac{r_T^2}{4u(1-u)} \stackrel{\text{LL}}{\approx} r_T^2 \approx R_T^2 \;\Rightarrow\; y_T = \frac{1}{2\pi b_0} \log\left[\frac{\alpha_s(Q_0^2)}{\alpha_s(R_T^2)}\right]$$

fissata R_T (M_h) $\rightarrow$ scala k_i^2 al branching non e` piu` arbitraria ($Y > y > y_0$)



termine B
R_T soft $\approx Q_0$

1. Jet Calculus
2. **Frammentazione in 2 adroni**
3. 2h SIDIS

1. e+e- $\rightarrow h_1\, h_2 + X$ a NLO
2. DiFF
3. **extDiFF**

Evoluzione di extended DiFF (extDiFF) $\Leftrightarrow$ DiFF(M_h)

$$\begin{aligned}
D^{i\to h_1 h_2}(z_1,z_2,Y) &= E_i^{a_1,a_2}(Y)\otimes D^{a_1\to h_1}(z_1,y_0)\otimes D^{a_2\to h_2}(z_2,y_0)\\
&\quad + E_i^{a}(Y-y_0)\otimes D^{a\to h_1 h_2}(z_1,z_2,y_0)\\
&= \int dR_T^2 \frac{d}{dR_T^2}\, E_i^{a_1,a_2}(Y)\otimes D^{a_1\to h_1}(z_1,y_0)\otimes D^{a_2\to h_2}(z_2,y_0)\,\theta(y_T-y_0)\\
&\quad + \int dR_T^2\, E_i^{a}(Y-y_0)\otimes D^{a\to h_1 h_2}(z_1,z_2,R_T^2,y_0)\,\theta(y_0-y_T)
\end{aligned}$$

$$\begin{aligned}
D^{i\to h_1 h_2}(z_1,z_2,R_T^2,Y) &= \frac{\alpha_s(R_T^2)}{2\pi\, R_T^2}\, D^{b_1\to h_1}(z_1,y_T)\otimes D^{b_2\to h_2}(z_2,y_T)\otimes \hat{P}^{j}_{b_1 b_2}\otimes E_i^{j}(Y-y_T)\,\theta(y_T-y_0\\
&\quad + D^{a\to h_1 h_2}(z_1,z_2,R_T^2,y_0)\otimes E_i^{a}(Y-y_0)\,\theta(y_0-y_T)
\end{aligned}$$

$$\begin{aligned}
y_T &= \frac{1}{2\pi b_0}\,\log\frac{\alpha_s(Q_0^2)}{\alpha_s(R_T^2)}\\
dy_T &= \frac{1}{2\pi}\,\frac{\alpha_s(R_T^2)}{R_T^2}\,dR_T^2
\end{aligned}$$

1. Jet Calculus
2. **Frammentazione in 2 adroni**
3. 2h SIDIS

1. e+e- $\rightarrow$ h_1 h_2 + X a NLO
2. DiFF
3. **extDiFF**

$$
\begin{aligned}
\frac{d}{dY} D^{i\to h_1 h_2}(z_1, z_2, Y) \;&=\; D^{k\to h_1}(z_1, Y) \otimes D^{l\to h_2}(z_2, Y) \otimes \hat{P}^{i}_{kl} \\
&\quad + D^{k\to h_1 h_2}(z_1, z_2, Y) \otimes P_{ki}
\end{aligned}
$$

$$
\frac{d}{dY} D^{i\to h_1 h_2}(z_1, z_2, R_T^2, Y) \;=\; D^{k\to h_1 h_2}(z_1, z_2, R_T^2, Y) \otimes P_{ki}
$$

extDiFF = DiFF ($M_h^2 \leftrightarrow R_T^2$) : scala soft R_T^2 rompe la degenerazione A-B
evoluzione semplice come fattorizzazione in 1 adrone
teorema di fattorizzazione come " " " " con stesso kernel

$$
\frac{d\sigma^{NLO}}{dz_1\, dz_2\, dR_T^2} = \sum_i d\hat{\sigma}_i^{NLO}(Q^2) \otimes D^{i\to h_1 h_2}(R_T^2, Q^2)
$$

a NLO e LL

Ceccopieri, Radici, Bacchetta, hep-ph/0703265

1. Jet Calculus
2. **Frammentazione in 2 adroni**
3. 2h SIDIS

1. e+e- $\rightarrow h_1\, h_2 + X$ a NLO
2. DiFF
3. **extDiFF**

Polarized extDiFF

$$\int d\mathbf{k}_T \quad \Delta^{[\Gamma]} = \frac{1}{4z} \int dk^+ \, \mathrm{Tr}\left[\Gamma \Delta(k, P_h, R)\right] \Big|_{k^- = P_h^-/z}$$

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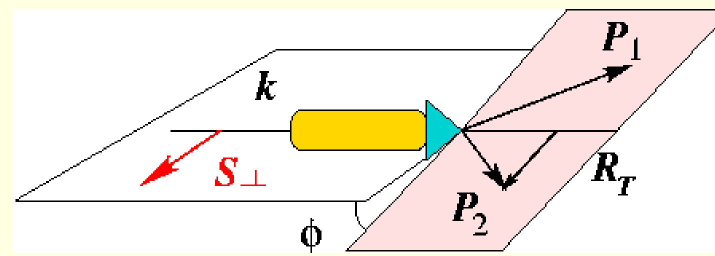
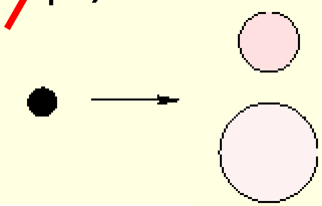
$\Delta^{[\Gamma]}\,(z,\zeta,M_h^2,\phi,\cancel{\mathbf{k}_T^2})$

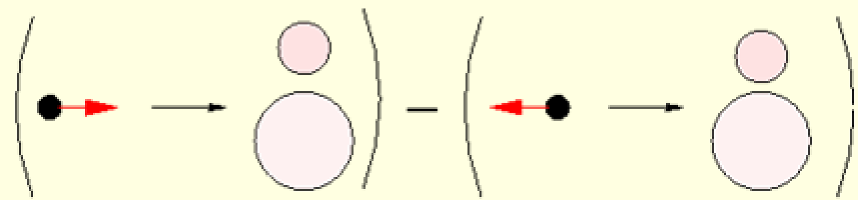


t=2 $\quad \Delta^{[\gamma^-]} = D_1 =$

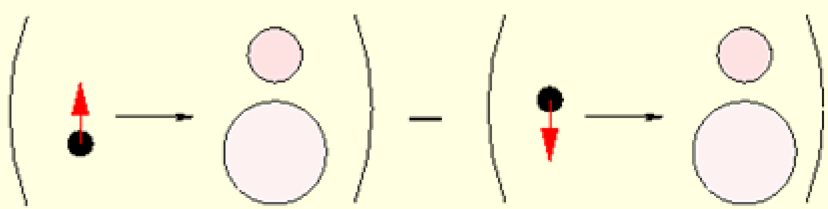


$$\Delta^{[\gamma^- \gamma_5]} = \frac{\epsilon_T^{ij} R_{Ti} k_{Tj}}{M_h^2} \cancel{G_1^\perp}$$

$G_1^\perp =$



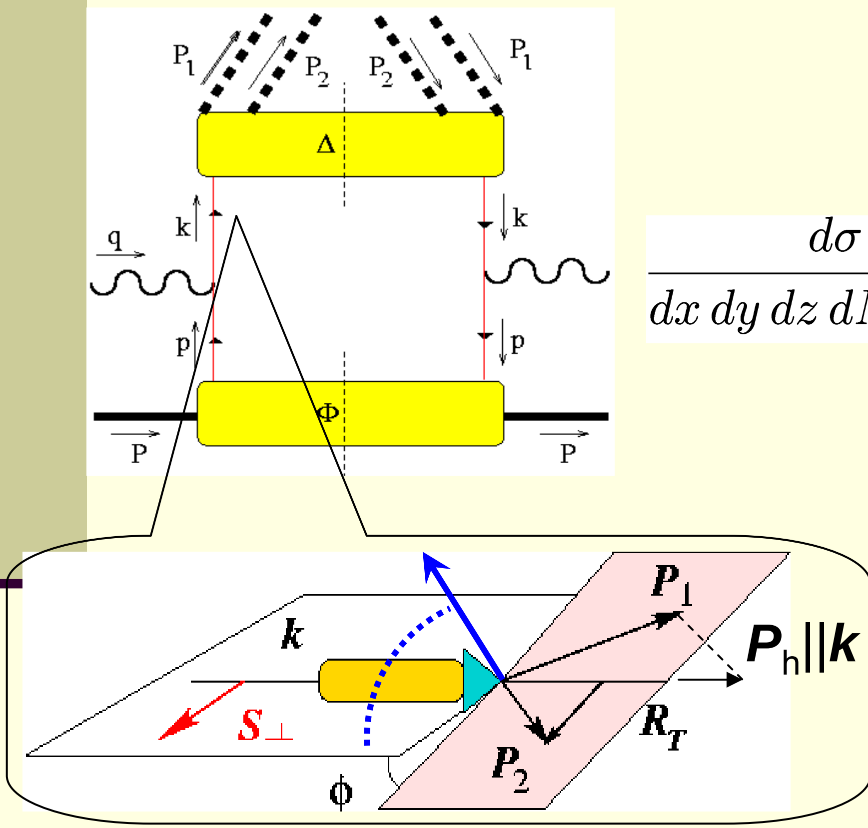
$$\Delta^{[i\sigma^{i-}\gamma_5]} = \frac{\epsilon_T^{ij} k_{Tj}}{M_h} \cancel{H_1^\perp} + \frac{\epsilon_T^{ij} R_{Tj}}{M_h} H_1^{\sphericalangle}$$



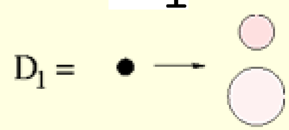
1. Jet Calculus
2. Frammentazione in 2 adroni
3. **2h SIDIS**

1. **cinematica**
2. SSA
3. modelli di DiFF
4. confronto con dati HERMES
5. confronto con dati COMPASS

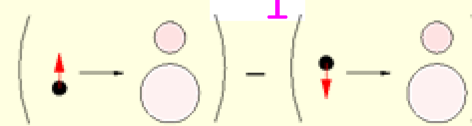
2h Semi-Inclusive Deep-Inelastic Scattering (2h SIDIS)



D_1



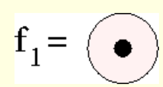
$H_1^{\sphericalangle}$



(naïve T-) chiral-odd

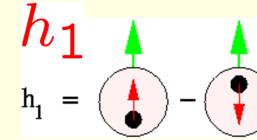
$$\frac{d\sigma}{dx\,dy\,dz\,dM_h^2\,d\phi_R} = \qquad \otimes$$

f_1



chiral-odd

trasversità h_1



asimmetria in

$$\begin{aligned}\cos\phi &= \cos(\phi_{S'_T} - (\phi_{R_T} + \frac{\pi}{2})) \\ &= \cos(\pi - \phi_{S_T} - (\phi_{R_T} + \frac{\pi}{2})) \\ &= \sin(\phi_{R_T} + \phi_{S_T})\end{aligned}$$

1. Jet Calculus
2. Frammentazione in 2 adroni
3. **2h SIDIS**

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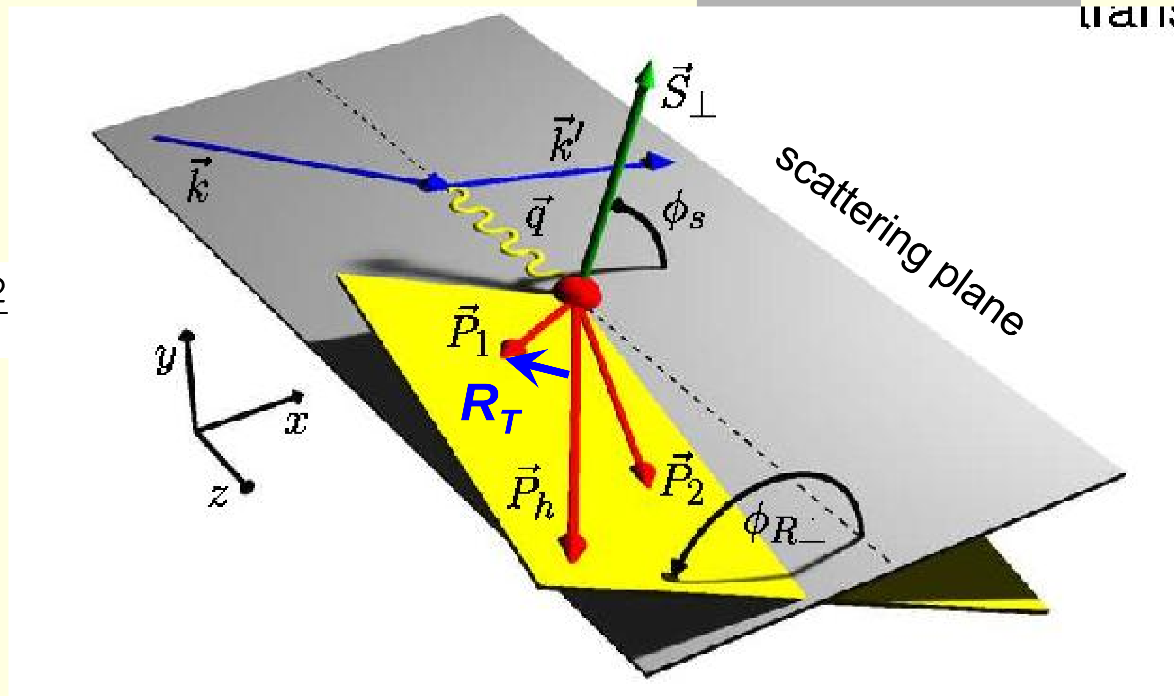
5. confronto con dati COMPASS

Cinematica 2h SIDIS

$$\hat{q} = \frac{\vec{q}}{|\vec{q}|} \parallel \hat{z} \qquad \vec{q} = \vec{k} - \vec{k}'$$

$$P_h = P_1 + P_2 \qquad R = \frac{P_1 - P_2}{2}$$



$$\cos\phi_S = \frac{(\hat{q}\times\vec{k})}{|\hat{q}\times\vec{k}|}\cdot\frac{(\hat{q}\times\vec{S})}{|\hat{q}\times\vec{S}|} \qquad \sin\phi_S = \frac{(\vec{k}\times\vec{S})\cdot\hat{q}}{|\hat{q}\times\vec{k}|\,|\hat{q}\times\vec{S}|}$$

$$\cos\phi_R = \frac{(\hat{q}\times\vec{k})}{|\hat{q}\times\vec{k}|}\cdot\frac{(\hat{q}\times\vec{R}_T)}{|\hat{q}\times\vec{R}_T|} \qquad \sin\phi_R = \frac{(\vec{k}\times\vec{R}_T)\cdot\hat{q}}{|\hat{q}\times\vec{k}|\,|\hat{q}\times\vec{R}_T|}$$

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Single Spin Asymmetry (SSA) in 2h SIDIS

$$\frac{d\sigma}{dx\, dy\, dz\, dM_h^2\, d\phi_{R_T}} = K \left\{ \sum_q e_q^2\, A(y)\, f_1^q(x)\, D_1^q(z,\zeta,M_h^2) \right. \quad \leftarrow \quad d\sigma_{UU}$$

$$d\sigma_{UT} \quad \rightarrow \quad \left. + \quad B(y)\, \frac{|\mathbf{S}_T||\mathbf{R}_T|}{M_h}\, \sin(\phi_{R_T}+\phi_{S_T}) \sum_q e_q^2\, h_1^q(x)\, H_1^{\sphericalangle\, q}(z,\zeta,M_h^2) \right\}$$

$$A_{UT}^{\sin(\phi_{R_T}+\phi_{S_T})} \equiv \frac{1}{\sin(\phi_{R_T}+\phi_{S_T})} \frac{d\sigma^\uparrow - d\sigma^\downarrow}{d\sigma^\uparrow + d\sigma^\downarrow} = \frac{1}{\sin(\phi_{R_T}+\phi_{S_T})} \frac{d\sigma_{UT}}{d\sigma_{UU}}$$

$$\propto \frac{B(y)}{A(y)} \frac{\sum_q e_q^2\, h_1^q(x)\, H_1^{\sphericalangle\, q}(z,\zeta,M_h^2)}{\sum_q e_q^2\, f_1^q(x)\, D_1^q(z,\zeta,M_h^2)}$$

info su DiFF da
e+e- $\rightarrow$ $(h_1 h_2)\,(h'_1 h'_2) + X$
Boer, Jakob, Radici,
P.R. D**67** (03) 094003
o da modelli

Jaffe, Jin, Tang, P.R.L. **80** (98) 1166 $\quad H_1^{\sphericalangle} \rightarrow \delta\hat{q}_I$

Radici, Jakob, Bianconi, P.R. D**65** (02) 074031

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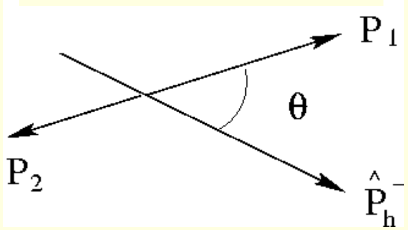
Espansione in onde parziali

2h c.m. frame



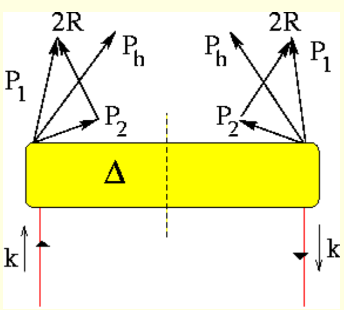
$\zeta = (z_1 - z_2) / (z_1 + z_2) = a(M_1,M_2,M_h) + b(M_1,M_2,M_h) \cos\theta$

$$\mathbf{DiFF}(z, \zeta(\cos\theta), M_h^2) = \Sigma_n \; \mathbf{DiFF}_n (z, M_h^2) \, P_n (\cos\theta)$$

$\int d\cos\theta \quad \dfrac{d\sigma}{\ldots\, d\cos\theta \,\ldots}$

$$D_1(z,\zeta,M_h^2) \to [D_1^{ss+pp}(z,M_h^2) + \cancel{D_1^{sp}\cos\theta + D_1^{pp}\frac{3\cos^2\theta - 1}{4}}]$$

$$H_1^{\sphericalangle} \to \left[H_1^{\sphericalangle sp}(z,M_h^2) + \cancel{H_1^{\sphericalangle pp}\cos\theta}\right]$$



naïve T-odd da Final-State Interactions (FSI)
→ interferenza tra canali in diff. di fase

$$\Delta(k, P_h, R) = \sum_X \int \frac{d^4\xi}{(2\pi)^4} e^{ik\cdot\xi} \langle 0|\psi(\xi)|P_1, P_2, X\rangle \langle P_1, P_2, X|\overline{\psi}(0)|0\rangle$$

$\sim |(\pi\pi)_{L=0}\rangle\langle(\pi\pi)_{L=1}| + |(\pi\pi)_{L=1}\rangle\langle(\pi\pi)_{L=0}|$

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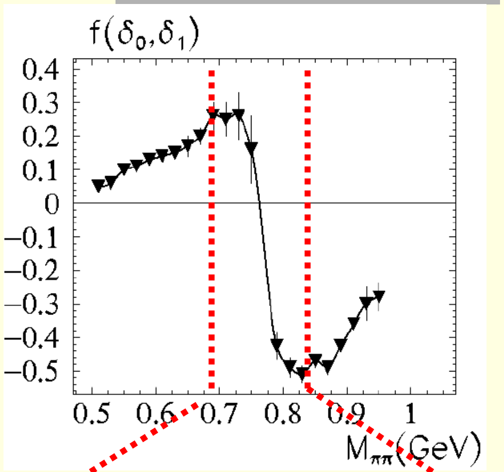
modelli pubblicati $ep^{\uparrow} \to e' \, (\pi^+\pi^-) \, X$

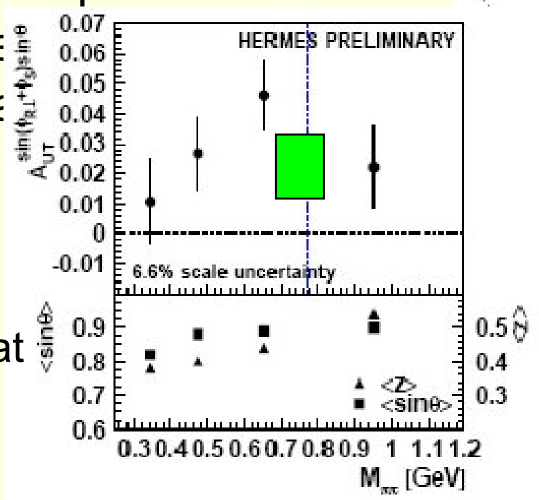
(Jaffe, Jin, Tang, P.R.L. **80** (98) 1166)

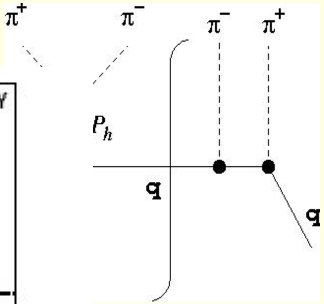
- interferenza s-p da scatt. elastico π-π
  solo phase shifts; cambio di segno da Re[ρ]

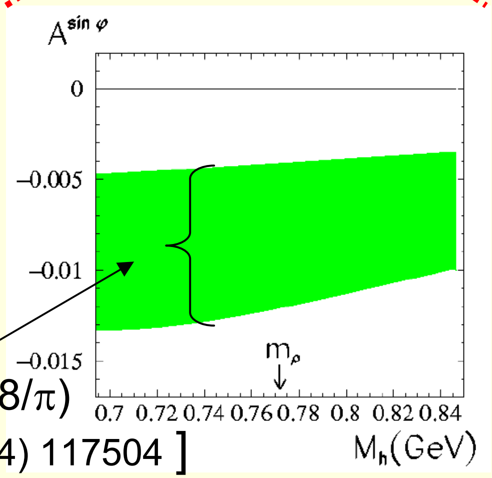


(Radici, Jakob, Bianconi, P.R. D**65** (02) 074031)

- modello spettatore
  interfe
- banda







P. van der Nat
DIS2005

Trento Conventions $\to$ x ($-8/\pi$)

[Bacchetta *et al.*, P.R. D**70** (04) 117504]

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Modello a spettatore upgraded

$$|P_1, P_2, X\rangle \sim |(\pi^+\pi^-)_L, \tilde{q}\rangle$$

[Bacchetta & Radici, P.R.D**74** (06) 114007]

1. background ≡ $q \to \pi^+\pi^- X_1$ no resonanza → real s-wave channel
2. $q \to \rho X_2 \to \pi^+\pi^- X_2$
3. $q \to \omega X_3 \to \pi^+\pi^- X_3$
4. $q \to \omega X'_4 \to \pi^+\pi^- \underbrace{(\pi^0 X'_4)}_{X_4}$

$X_1 = X_2 = X_3 = X_4 = X$

p-wave channel = coherent sum |2.+3.+4.|

Warning: $\omega \to [(\pi\,\pi)_{L=1}\,\pi]_{J=1}$

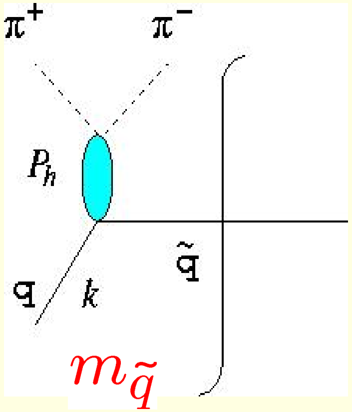
$\Rightarrow$ $\boxed{\text{max number of } (\pi^+\pi^-) \text{ pairs in s-p interference} \sim \mathcal{Im}\,[\text{ p-wave channel }]}$

parameters

s-wave $f_s\, e^{-k^2/\Lambda_s^2}$

p-wave
$$\Big[f_\rho\, \mathrm{BW}(M_h^2, m_\rho, \Gamma_\rho) + f_\omega\, \mathrm{BW}(M_h^2, m_\omega, \Gamma_\omega) + f_{\omega 3} \int dp_{\pi^0}\, \mathrm{BW}(M_{3\pi}^2, m_\omega, \Gamma_\omega)\Big]\, e^{-k^2/\Lambda_p^2}$$

$$\Lambda_{s/p} = \alpha_{s/p}\, z^{\beta_{s/p}}\, (1-z)^{\gamma_{s/p}}$$



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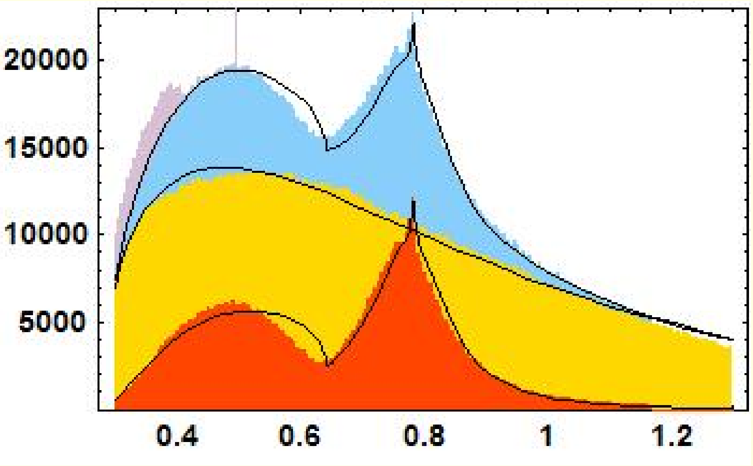
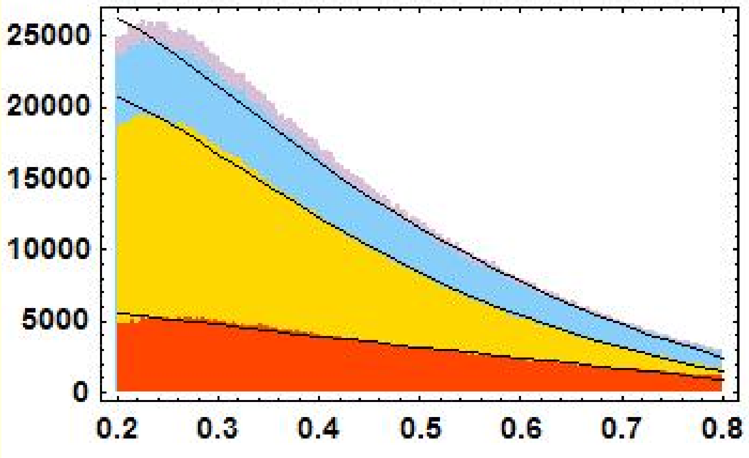
Fit delle distribuzioni in M_h e z dell'output di PYTHIA a HERMES



2.+3.+4. p-wave
1. background s-wave
Total
Total + 5.+6.

Bacchetta & Radici, P.R.D**74** (06) 114007

$$\alpha_s = 2.598 \pm 0.051 \text{ GeV}^2$$
$$\beta_s = -0.751 \pm 0.008$$
$$\gamma_s = -0.193 \pm 0.004$$
$$\alpha_p = 7.069 \pm 0.11 \text{ GeV}^2$$
$$\beta_p = -0.038 \pm 0.003$$
$$\gamma_p = -0.085 \pm 0.004$$
$$f_s = 1197.2 \pm 2.0 \text{ GeV}^{-1}$$
$$f_\rho = 93.49 \pm 1.58$$
$$f_\omega = 0.635 \pm 0.026$$
$$f_{\omega_3} = 450.83 \pm 7.02 \qquad \tilde{m}_q = 2.972 \pm 0.04 \text{GeV}$$



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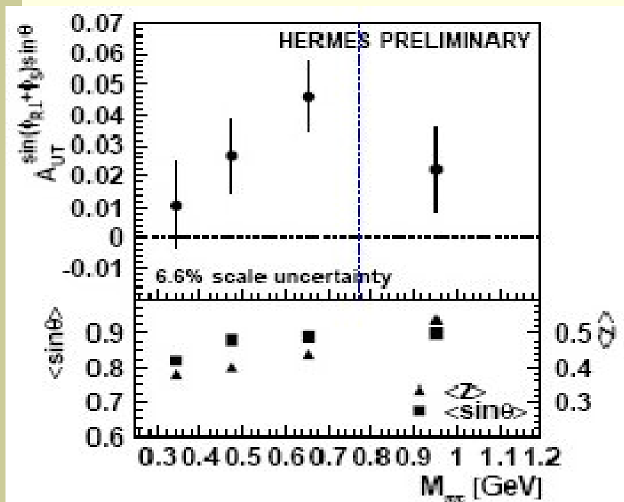
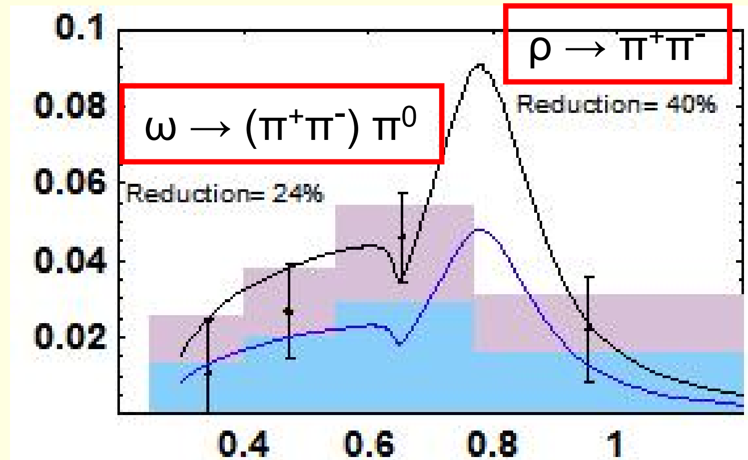
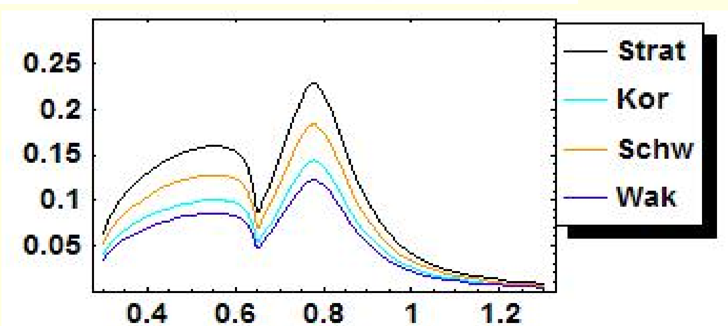
HERMES PRELIMINARY 6.6% scale uncertainty

$Q^2>1$ GeV^2 $s=56.2$ GeV^2





$$A_{UT}^{\sin(\phi_R+\phi_S)}(\mathrm{bin}[M_h]) = \frac{\int_{\mathrm{bin}} dM_h\, 2M_h \int_{0.2}^{0.8} dz \ldots}{\int_{\mathrm{bin}} dM_h\, 2M_h \int_{0.2}^{0.8} dz \ldots}$$



Strat
Soffer *et al.*,
P.R. **D65** (02) 114024

Kor
Korotkov *et al.*,
E.P.J. **C18** (01) 639

Schw
Schweitzer *et al.*
P.R. **D64** (01) 034013

Wak
Wakamatsu
P.L. B**509** (01) 59

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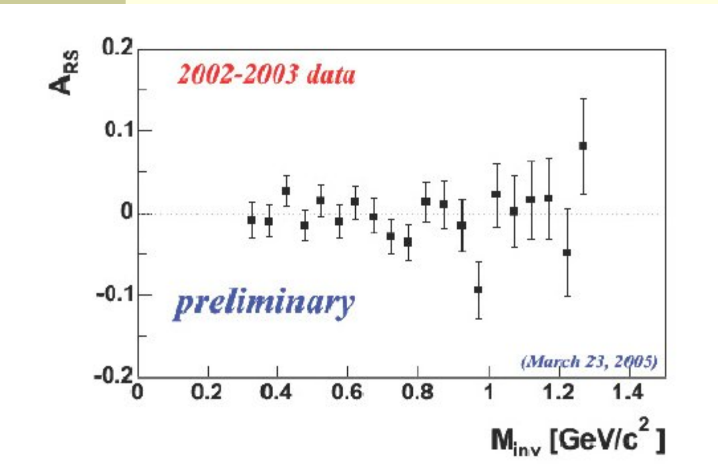
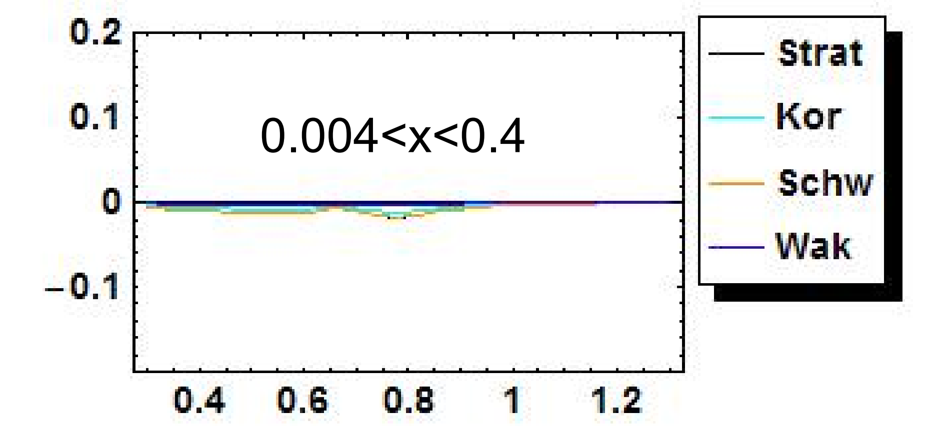
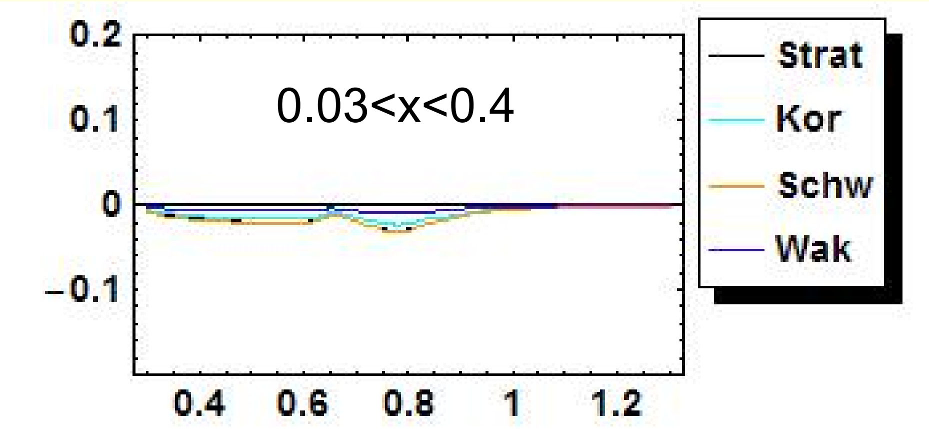
COMPASS deuterio Q^2>1 GeV^2 s=604 GeV^2



Joosten – DIS2005





simmetria d'isospin in d={p,n}

$$\frac{1}{9}[4u(x) - d(x) - \bar{u}(x) + \bar{d}(x) \\ +4d(x) - u(x) - \bar{d}(x) + \bar{u}(x)]$$

$$f_1^d \approx \frac{1}{2} f_1^u \qquad h_1^d \approx -\frac{1}{4} h_1^u$$