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Spin Polarization of Hyperons in the Hadron-Hadron Inclusive Collisions – *Mechanisms and Dynamics* –

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The Mechanisms and Dynamics

producing Spin-asymmetry distributions

through Hadron, Photon, Lepton reactions

within a Global Quark-Rearrangement model.

The Spin polarization
in the hyperon productions.

In particular, Diquarks; Scala + Vector

(1) *The Schwinger mechanisms*

(2) *The Form factor effect*

From 1992 to 2003

(1) The Standard cases; *FSU / SSD*

(2) The Valence parton-less cases; $pp \rightarrow \overline{\Lambda}(\bar{u}\bar{d}\bar{s})X$

The *primary quark* mechanism.

(3) Through EM-interaction; $\gamma p \rightarrow \Lambda X$, $P(\Lambda)$

The *primary quark* mechanism.

(4) Through weak-interaction; $\nu_{\mu} p \rightarrow \Lambda \mu^{-} X$, $P(\Lambda)$

Weak-boson exchange mechanism.

(5) The Non-spin transfer process; $\vec{p}p \rightarrow \Lambda X, D_{NN}(\Lambda) \neq 0$

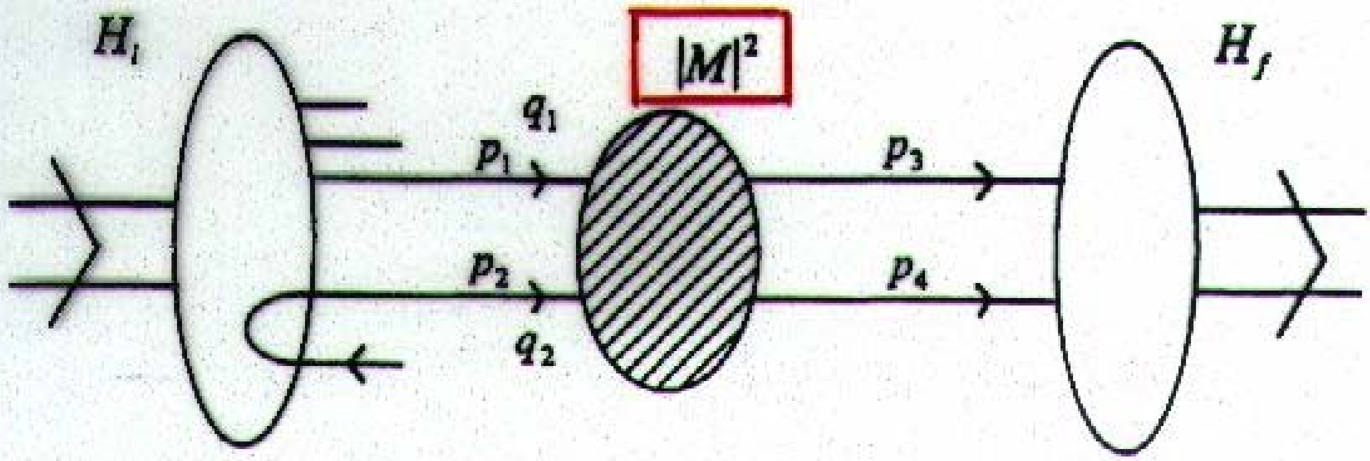
One-gluon propergation mechanism.

(6) Exclusive; $\vec{p}p \rightarrow \Lambda K^{+} p$, $D_{NN}(\Lambda)$

(7) The 5-q Baryon; $\gamma n \rightarrow \theta^{+}(uudd\bar{s})K^{-}$, $P(\theta^{+})$?

1. The Microscopic Quark Recombination Model

Y. Yamamoto, K.-I. Kubo and H. Toki, PTP 98(1997)95.

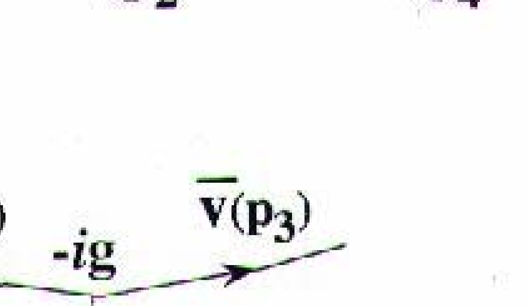


1. $pp \to \Lambda X$

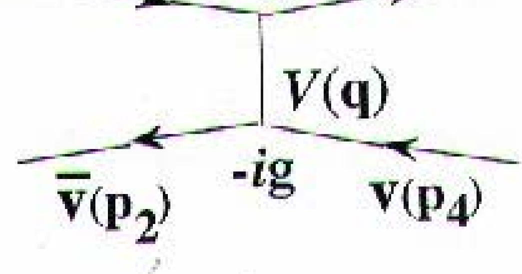
$(ud)_0$

2. $pp \to \Sigma^+ X$

$(uu)_1$



3. $pp \to \pi X$



$$\sigma_{s_a s_b s_c}(x_F, P_T) = \prod_{i=1}^{4} \left[\int_{x_{i,\min}}^{x_{i,\max}} dx_i \int_{y_{i,\min}}^{y_{i,\max}} dy_i \int_{z_{i,\min}}^{z_{i,\max}} dz_i / E_i \right]$$

$$\times \sum_{s_1 s_2 s_3 s_4} G_1^{s_a s_1}(x_1 y_1 z_1)\, G_2^{s_b s_2}(x_2 y_2 z_2)\, G_3^{s_c s_3}(x_3 y_3 z_3)\, G_4^{s_c s_4}(x_4 y_4 z_4)$$

$$\times | M(p_1{}^{s_1} p_2{}^{s_2} p_3{}^{s_3} p_4{}^{s_4}) |^2\, \delta^4(p_1 + p_2 - p_3 - p_4)\, \delta^3(\mathbf{p}_3 + \mathbf{p}_4 - \mathbf{p}_H)$$

$$\boldsymbol{p}_i = \left(p_{ix}, p_{iy}, p_{iz}\right)$$

$$x_1 = p_{1x} / p_{\mathrm{cm}}, \quad y_1 = p_{1y} / p_{\mathrm{t}}, \quad z_1 = p_{1z} / p_{\mathrm{t}}$$

$$M = M^{(2)} + \sqrt{(E_4 + m_2)(E_2 + m_2)}\, I^{(\mathrm{h})}$$

Leading term $M^{(2)}$

- **Scalar diquark case;** $Ex.\ pp \to \Lambda\left([ud]_0 s\right) X$

$$-iM^{(2)} = -g^2 V(q)\bar{v}(p_4 s_4) v(p_2 s_2)$$

- **Vector diquark case;** $Ex.\ pp \to \Sigma^+\left([uu]_1 s\right) X$

$$-iM^{(2)} = -g^2 V(q)\varepsilon^*(p_3 s_3)\varepsilon(p_1 s_1)\bar{v}(p_4 s_4) v(p_2 s_2)$$

- **Meson production case;** $Ex.\ pp \to \pi^+ (u\bar{d}) X$

$$-iM^{(2)} = -g^2 V(q)\bar{v}(p_4 s_4) v(p_2 s_2)\bar{v}(p_3 s_3) v(p_1 s_1)$$

$v(p_i s_i)$; Dirac spinor, $v^{(\mu_i)}(p_i s_i) = N \begin{pmatrix} \chi^{(\mu_i)} \\ \dfrac{\sigma_i \cdot p_i}{E_i + m_i}\chi^{(\mu_i)} \end{pmatrix}$

$\varepsilon(p, s)$; Polarization vector

$$\varepsilon^{(\mu)}(p, s) = \left(\frac{p \cdot s^{(\mu)}}{m},\ s^{(\mu)} + \frac{\left(p \cdot s^{(\mu)}\right)p}{m(E + m)} \right)$$

$s^{(\mu)}$; Spin tensor $s^{(\pm 1)} = \mp\frac{1}{\sqrt{2}}(1, \pm i, 0)$, $s^{(0)} = (0, 0, 1)$

$$\left|M\left(\mu_4=\mu_2=\pm\frac{1}{2};\mu_3=\mu_1=\mu\right)\right|^2=g^4V^2$$

$$\times\left[\sigma_{\mathrm{ind}}^{\mathrm{S,V}}(x_{\mathrm{F}},p_{\mathrm{t}};x_i,y_i,z_i)\pm R^{\mathrm{S,V}}\sigma_{\mathrm{dep}}^{\mathrm{S,V}}(x_{\mathrm{F}},p_{\mathrm{t}};x_i,y_i,z_i)\right]$$

$$R^{\mathrm{S,V}}=-\mathrm{Im}\left[I^{(\mathrm{h})\mathrm{S,V}}\right]/g^2V\rightarrow \text{constant param' rs}$$

$$\left\langle\sigma_{\mathrm{ind}}^{\mathrm{S}}(x_{\mathrm{F}},p_{\mathrm{t}})\right\rangle=\int G(x_i,y_i,z_i)\sigma_{\mathrm{ind}}^{\mathrm{S}}(x_{\mathrm{F}},p_{\mathrm{t}};x_i,y_i,z_i)\quad \text{etc.}$$

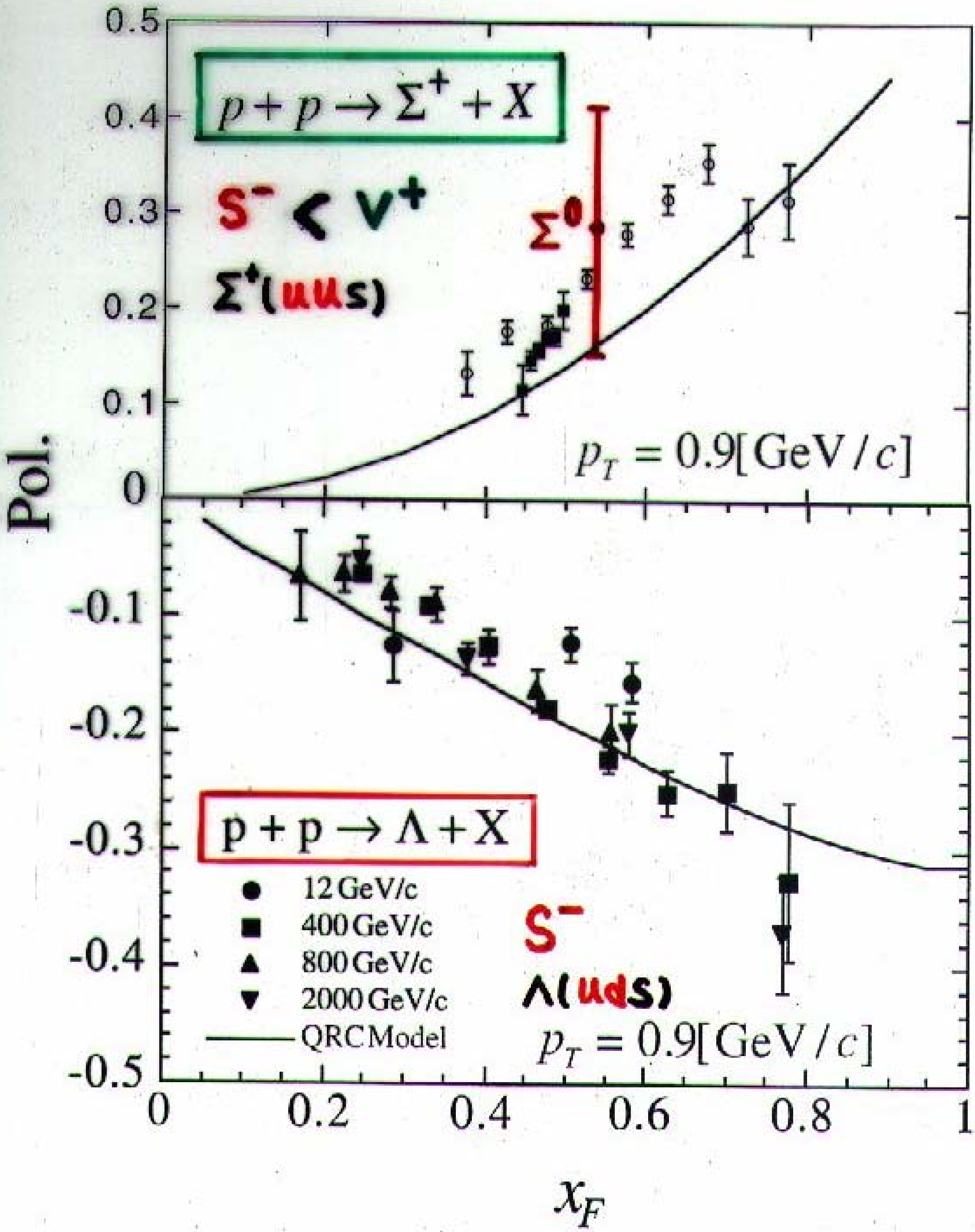
$$P(x_{\mathrm{F}},p_{\mathrm{t}})=\frac{R^{\mathrm{S}}\left\langle\sigma_{\mathrm{dep}}^{\mathrm{S}}\right\rangle+R^{\mathrm{V}}\left\langle\sigma_{\mathrm{dep}}^{\mathrm{V}}\right\rangle}{\left\langle\sigma_{\mathrm{ind}}^{\mathrm{S}}\right\rangle+\left\langle\sigma_{\mathrm{ind}}^{\mathrm{V}}\right\rangle}$$

R^{S}; $pp\rightarrow\Lambda((ud)_0 s)X$ 10 GeV

R^{V}; $pp\rightarrow\Sigma^+((uu)_1 s)X$ 20 GeV

S + V; $\Sigma^- p\rightarrow\Xi^- X$ $pp\rightarrow\Sigma^- X$

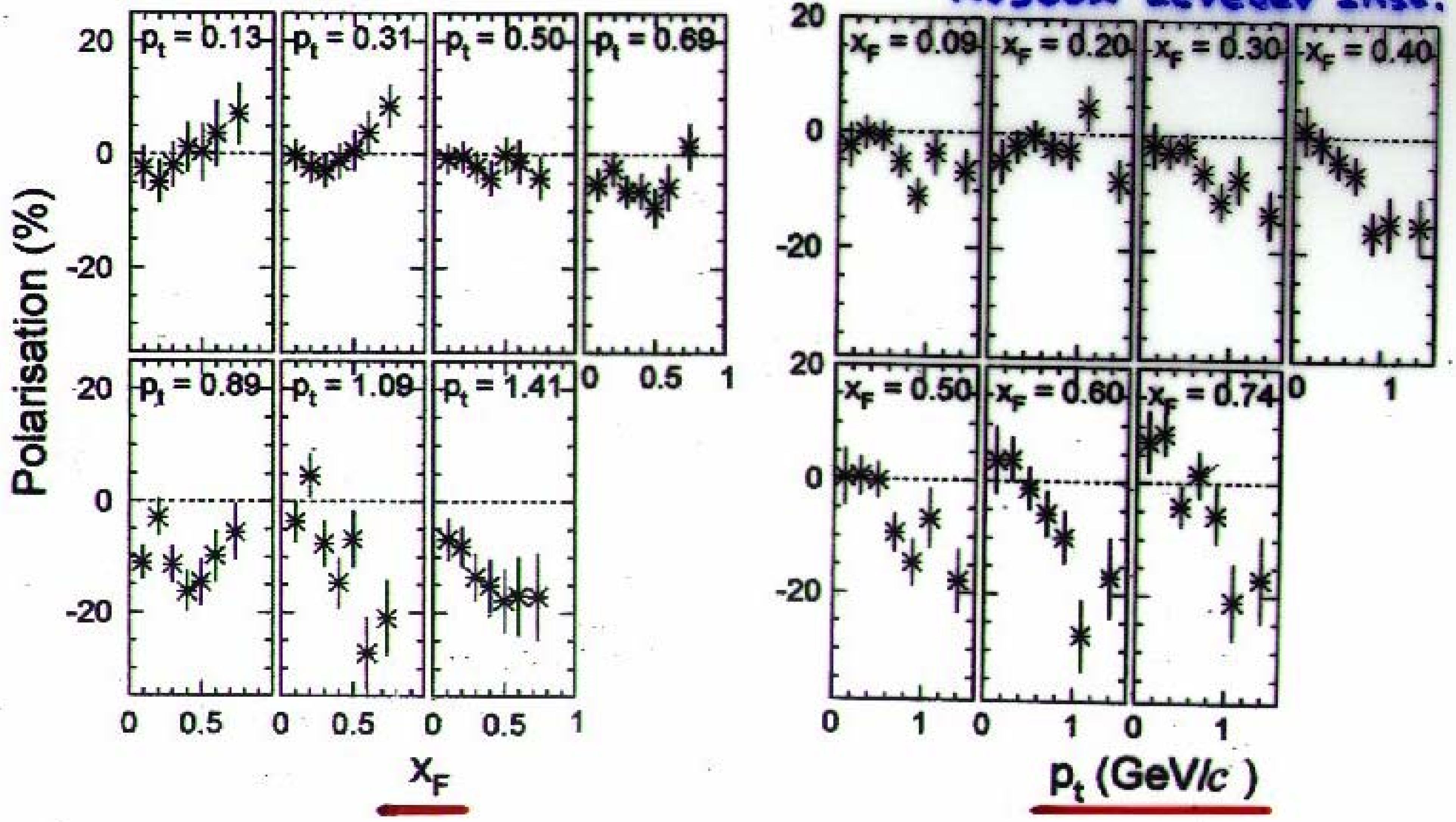
$\gamma p\rightarrow\Lambda X$ $\nu_\mu p\rightarrow\Lambda\mu^- X$



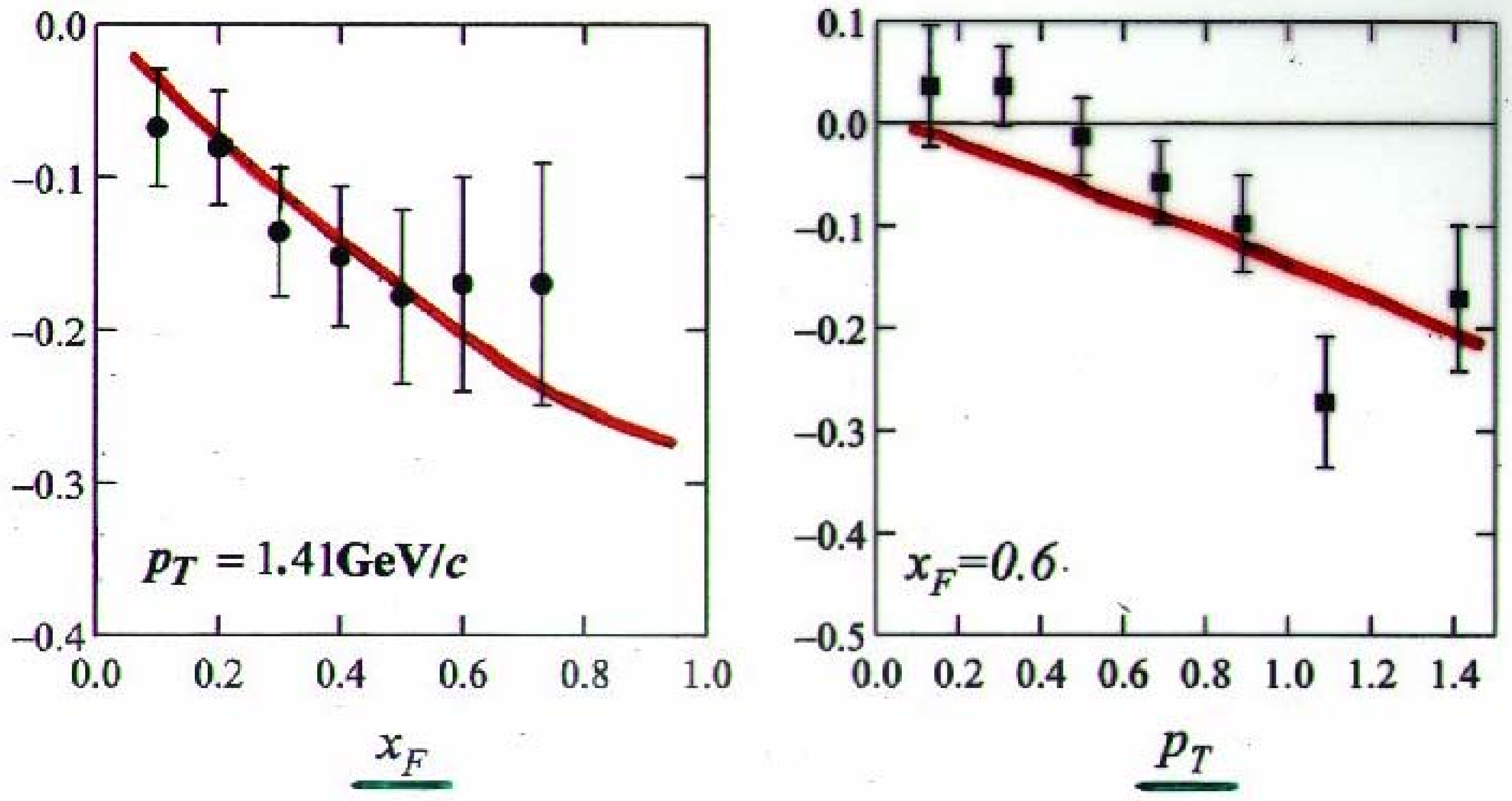
p + p → Σ⁺ + X
S⁻ < V⁺
Σ⁺(uus)
Σ⁰
p_T = 0.9[GeV/c]
Pol.
p + p → Λ + X
12 GeV/c
400 GeV/c
800 GeV/c
2000 GeV/c
QRC Model
S⁻
Λ(uds)
p_T = 0.9[GeV/c]
x_F

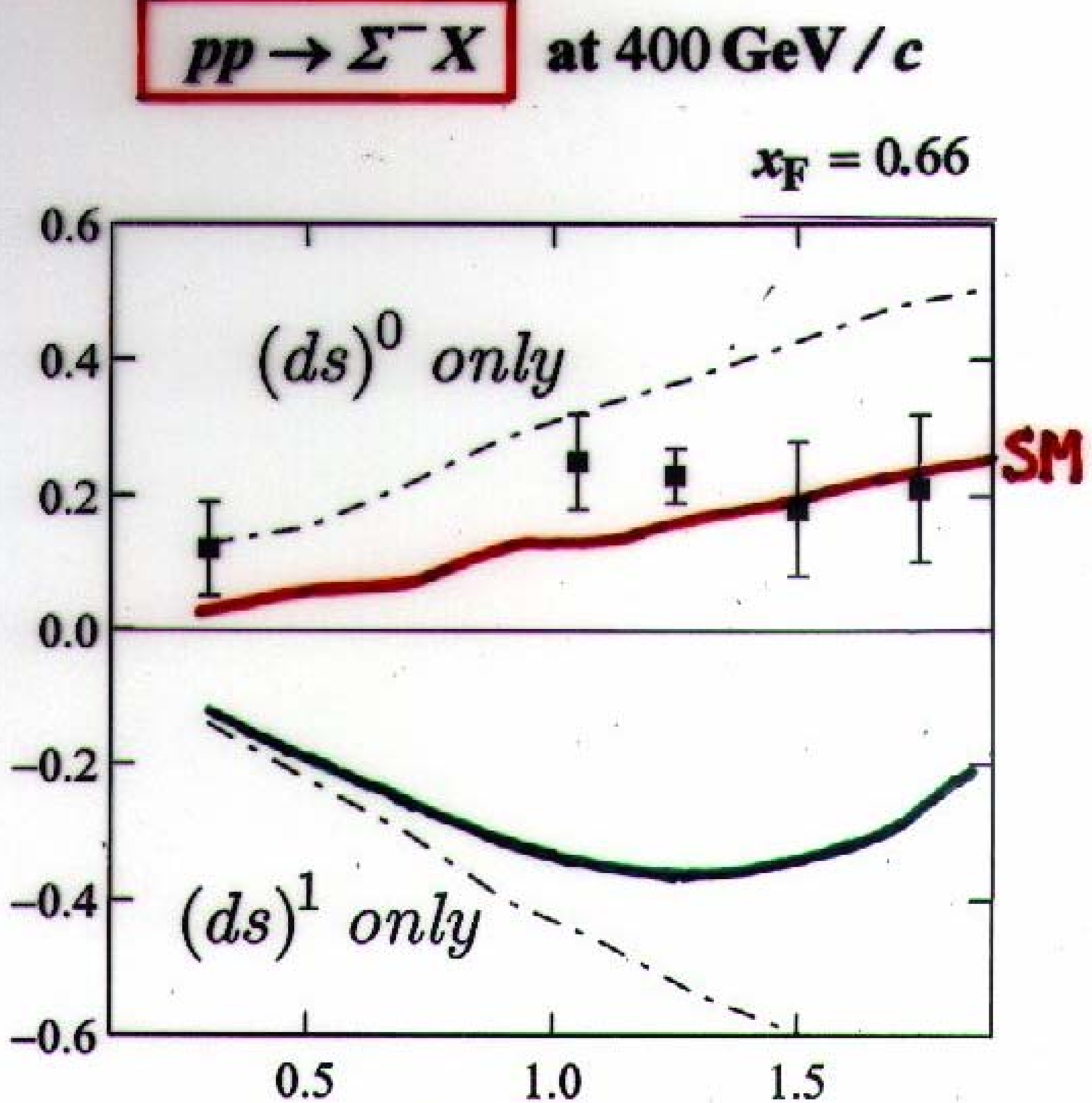
Spin polarization; $\Sigma^- A \to \Xi^- X$ at 340 GeV/c

M.I.Adamovich et al.
Moscow Levedev Inst.



Spin polarization; $\Sigma^- A \rightarrow \Xi^- X$ at 340 GeV/c





pp → Σ⁻X at 400 GeV / c
x_F = 0.66
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
(ds)^0 only
(ds)^1 only
SM
0.5
1.0
1.5
P_T [GeV/c]

(1) The Schwinger mechanisms

The quark and diquark production rates from sea strongly depend on masses of them.

The mass of diquark depends on its internal spin state,

Scalar or Vector ; $m_S(q_1 q_2) < m_V(q_1 q_2)$

$$C_{SM}^{S,V} = \exp\left\{ -\pi \left(m_{S,V}^2 + k_T^2 \right) / \kappa \right\}$$

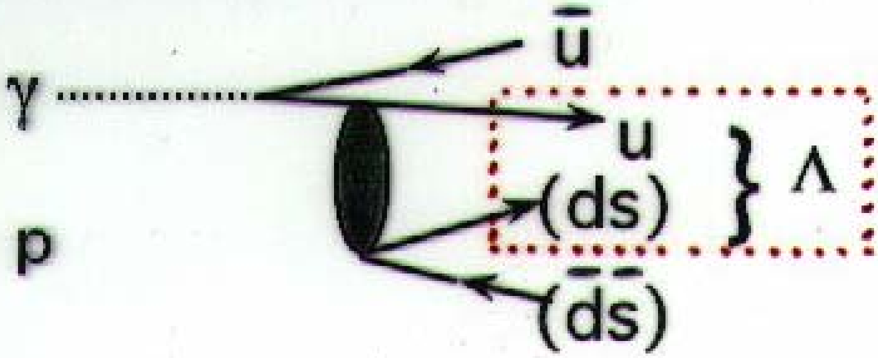
$$P(x_F, p_t) = \frac{R_s \left\langle C_{SM}^S \sigma_{dep}^S \right\rangle + R_v \left\langle C_{SM}^V \sigma_{dep}^V \right\rangle}{\left\langle C_{SM}^S \sigma_{ind}^S \right\rangle + \left\langle C_{SM}^V \sigma_{ind}^V \right\rangle}$$

e.g. $$\left\langle C_{SM}^S \sigma_{dep}^S \right\rangle \equiv \int \sum_{\substack{possible\ quark \\ components}} C_{SM}^S\, G(x_i, y_i, z_i)\, \sigma_{dep}^S(x_F, p_t; x_i, y_i, z_i)$$

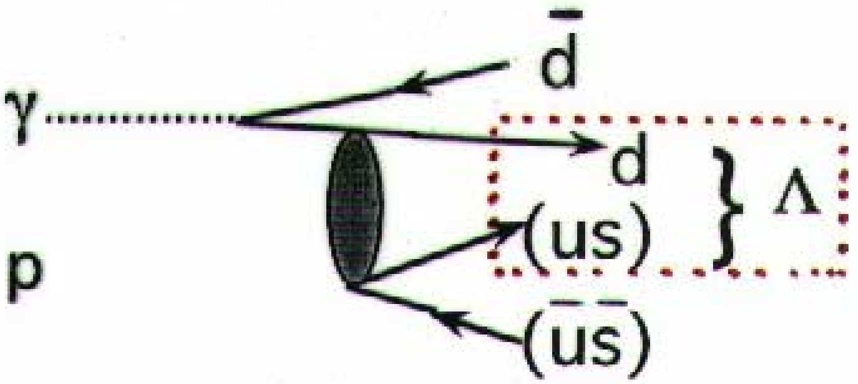
3 $\gamma p \rightarrow \Lambda X$; Λ–spin polarization

The Primary Quarks Creation Mechanism

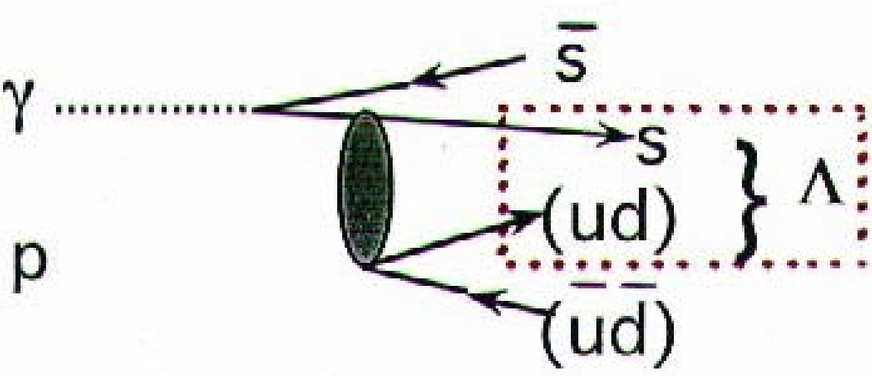
$X_F > 0$; Beam Fragmentation



P = - $\delta/2$

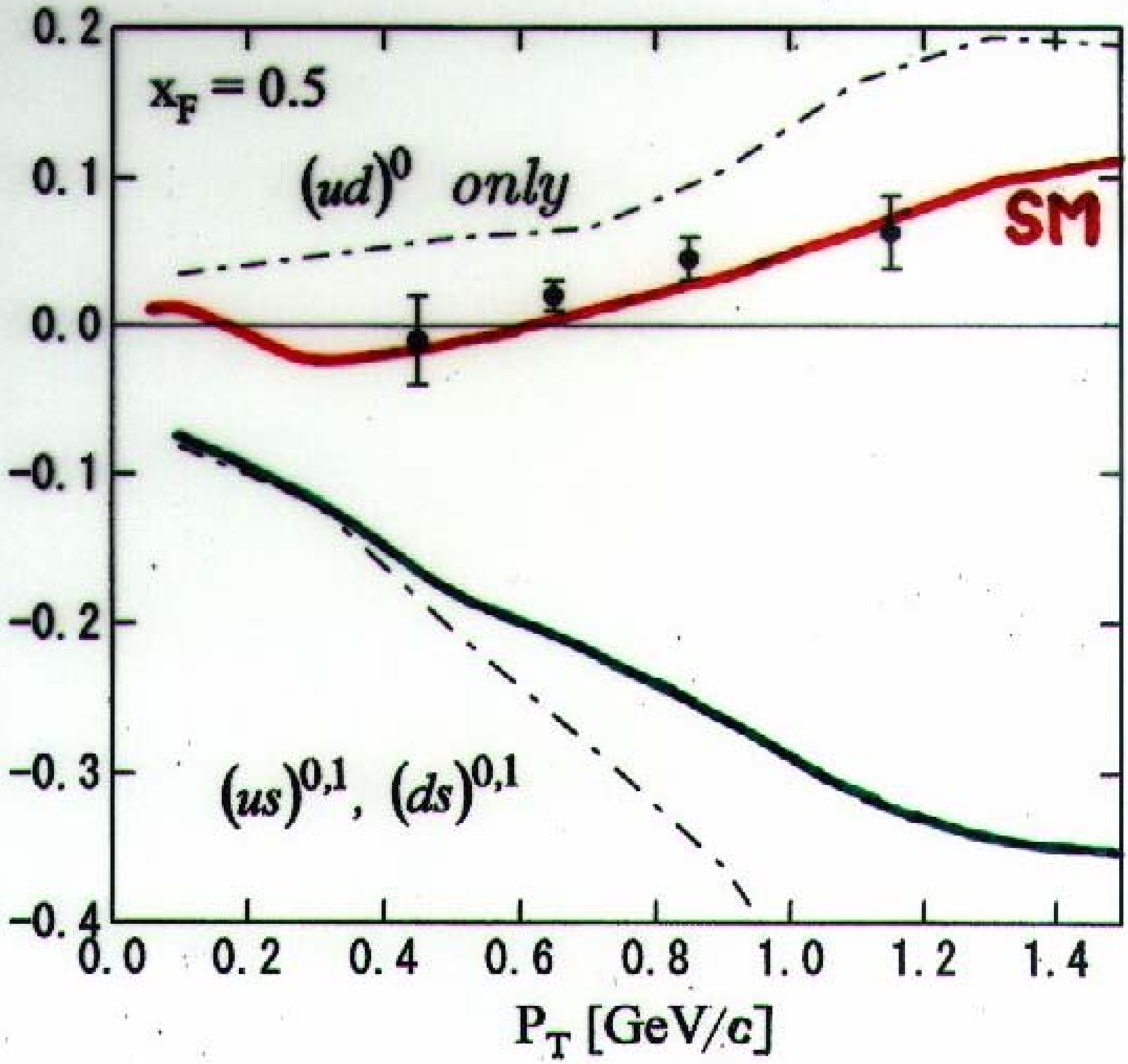


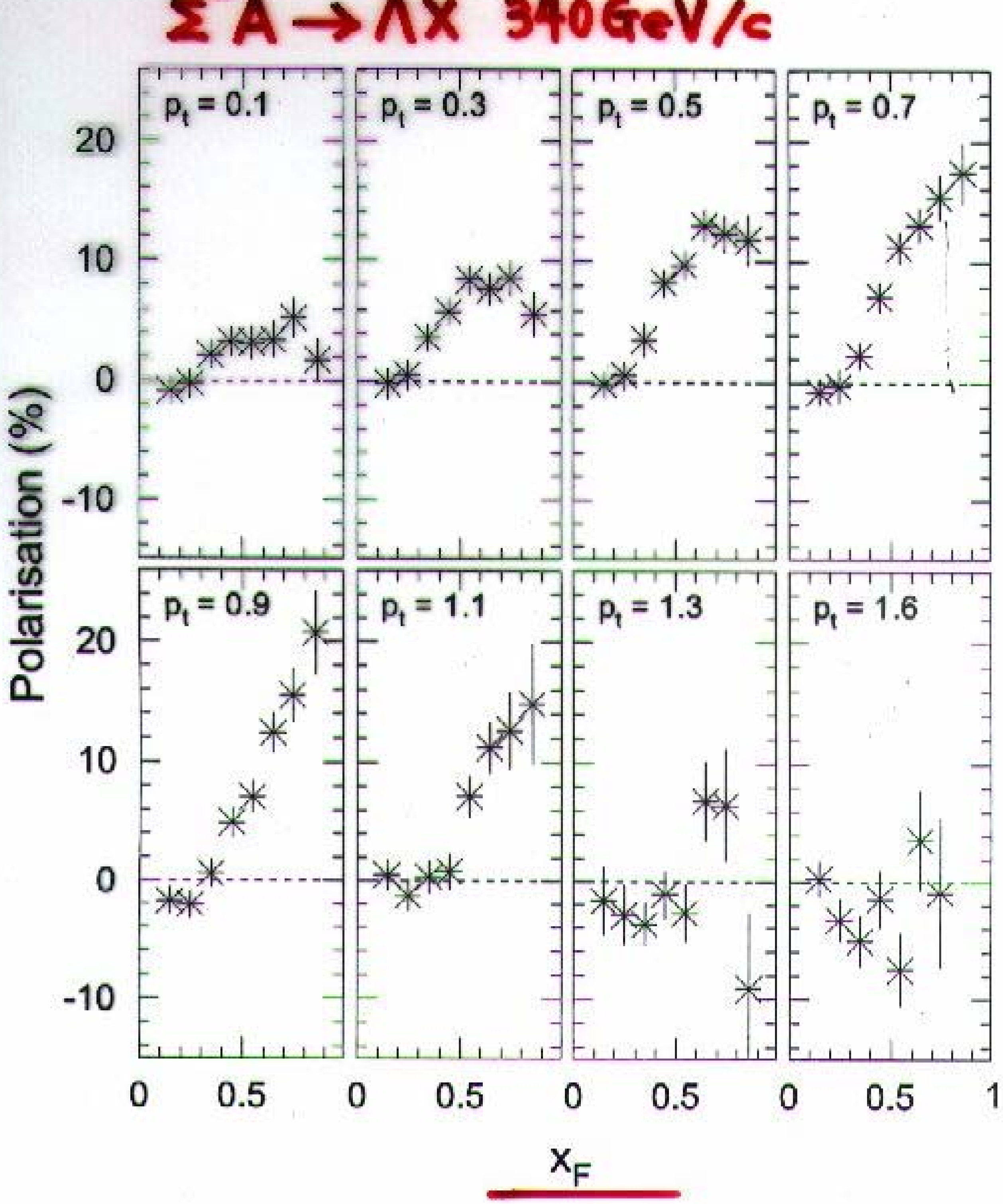
P = - $\delta/2$



P = ε

Spin polarization; $\gamma p \to \Lambda X$ at $< E_\gamma >= 16$ GeV/c

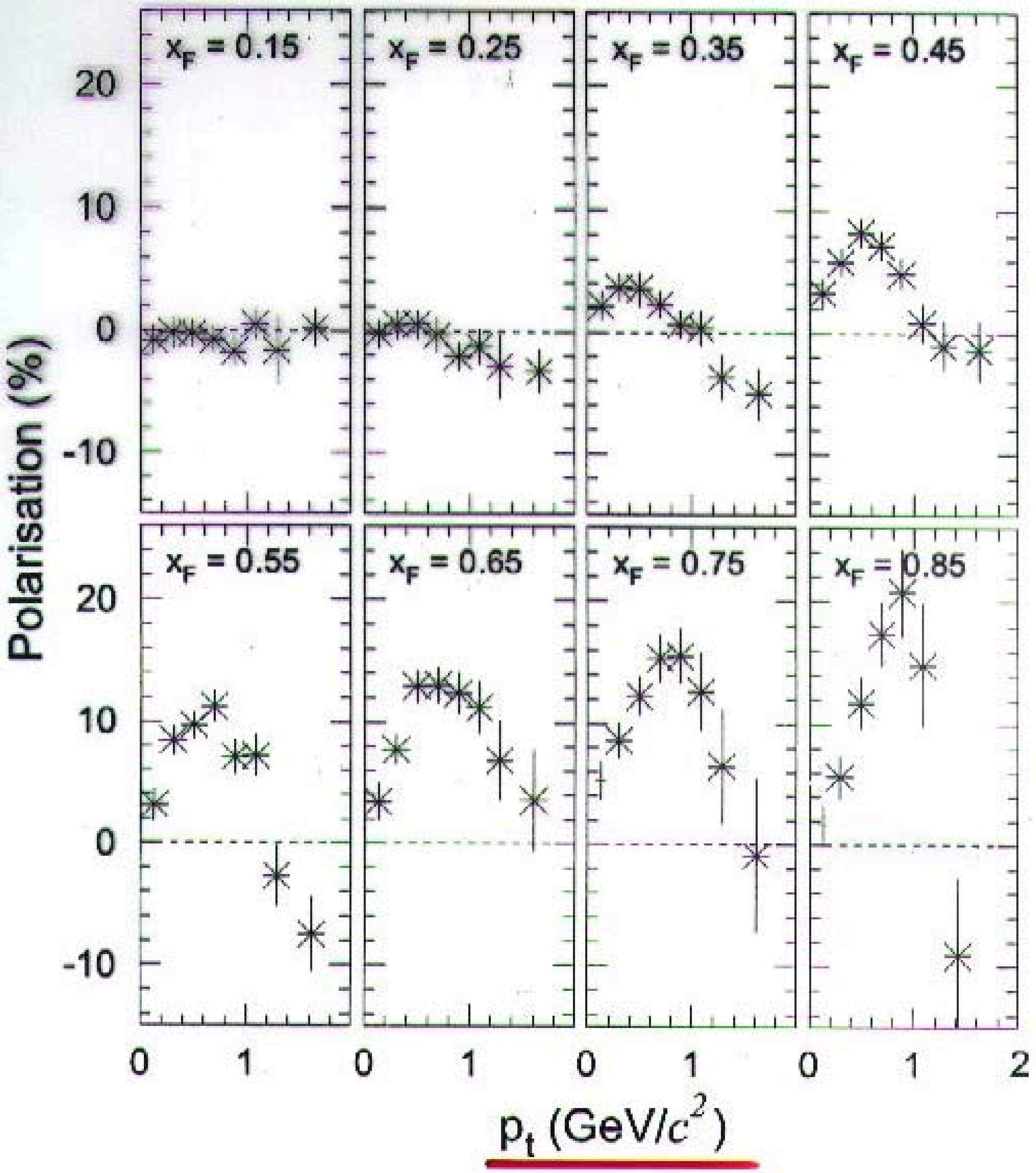




Σ⁻A → ΛX 340GeV/c
p_t = 0.1
p_t = 0.3
p_t = 0.5
p_t = 0.7
p_t = 0.9
p_t = 1.1
p_t = 1.3
p_t = 1.6
Polarisation (%)
20
10
0
-10
0
0.5
1
x_F

M.I.Adamovich et al., EPJ (Moscow Lebedev Ins.)

$\Sigma^- A \to \Lambda X$ 340 GeV/c A=C, Cu



(2) The form factor effect

Extension of diquark in the configuration space should be different between Scalar and Vector diquarks by reflecting attractive or repulsive nature of the force acting between the two quarks.

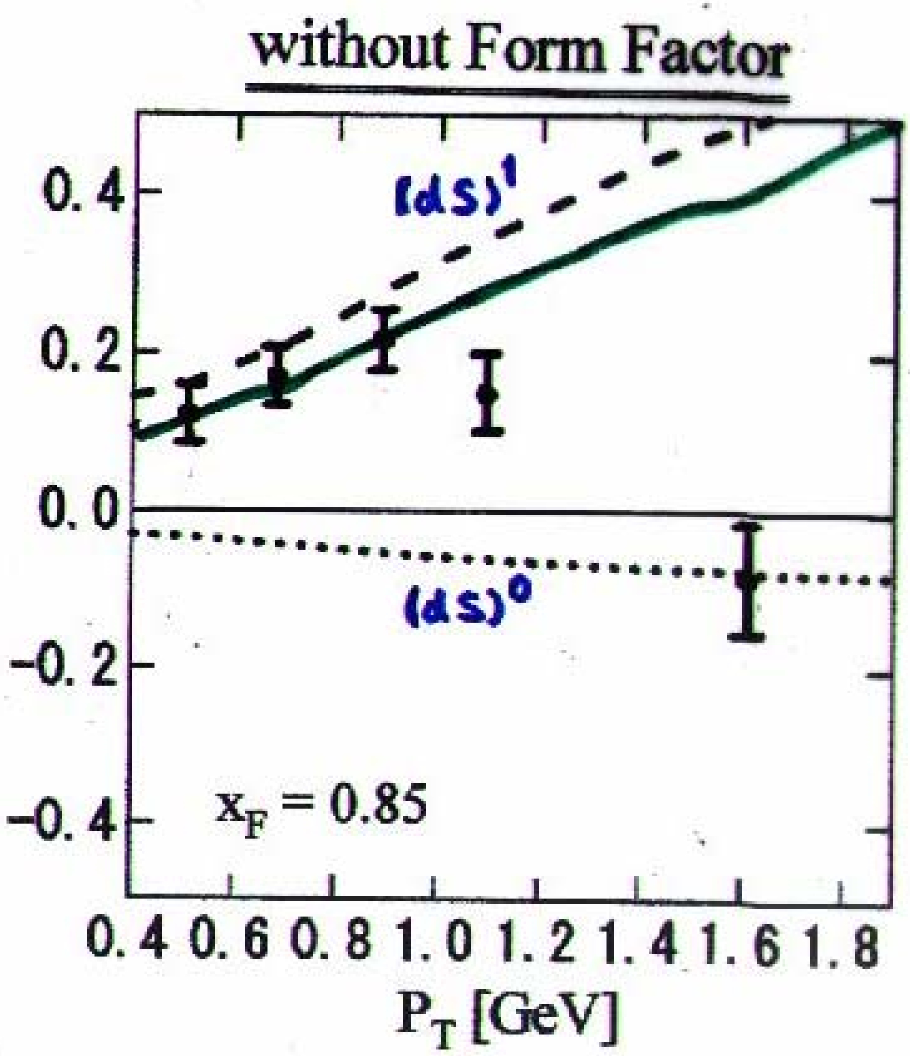
We multiply a factor $\exp\left(-r^2 P_t^2\right)$ to the each cross section, with a condition, r ; $r_S < r_V$.

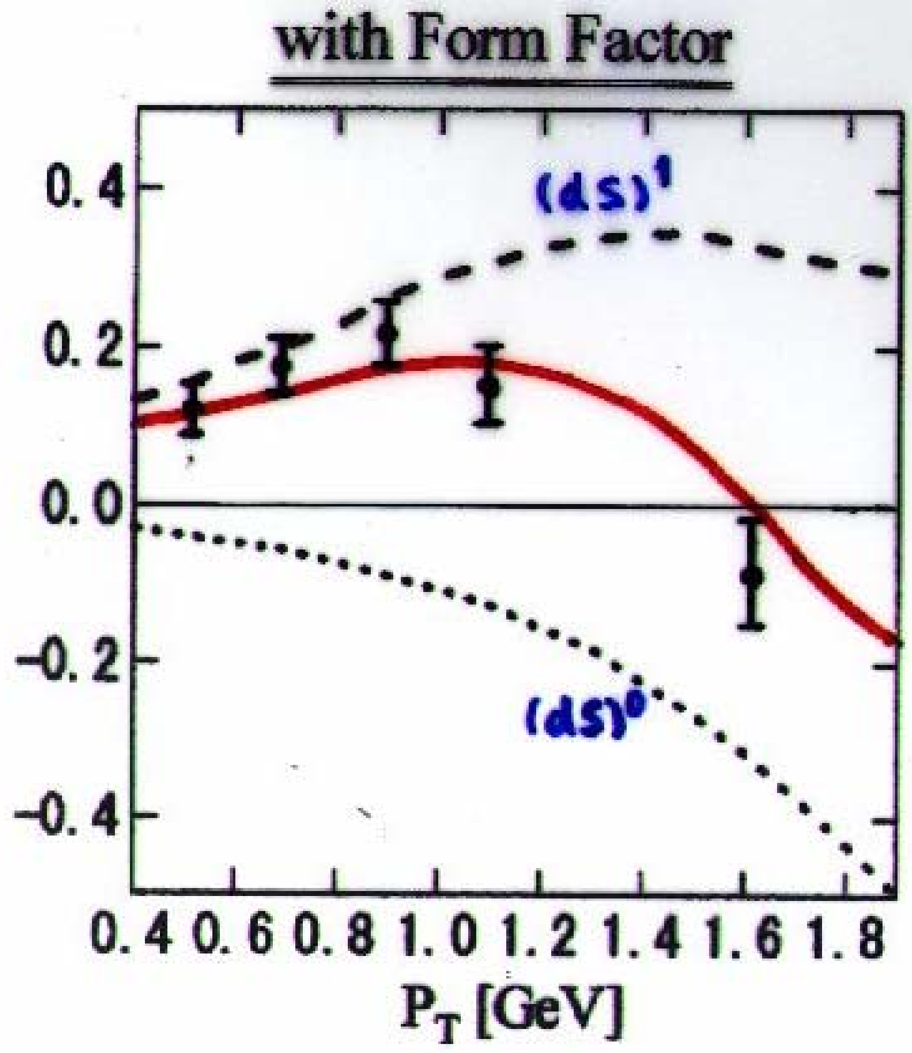
The spin polarization;

$$P(x_F, P_t) = \frac{R_S \exp\left(-r_S^2 P_t^2\right)\left\langle \sigma_{dep}^{S} \right\rangle + R_V C_V \exp\left(-r_V^2 P_t^2\right)\left\langle \sigma_{dep}^{V} \right\rangle}{\exp\left(-r_S^2 P_t^2\right)\left\langle \sigma_{ind}^{S} \right\rangle + C_V \exp\left(-r_V^2 P_t^2\right)\left\langle \sigma_{ind}^{V} \right\rangle}$$

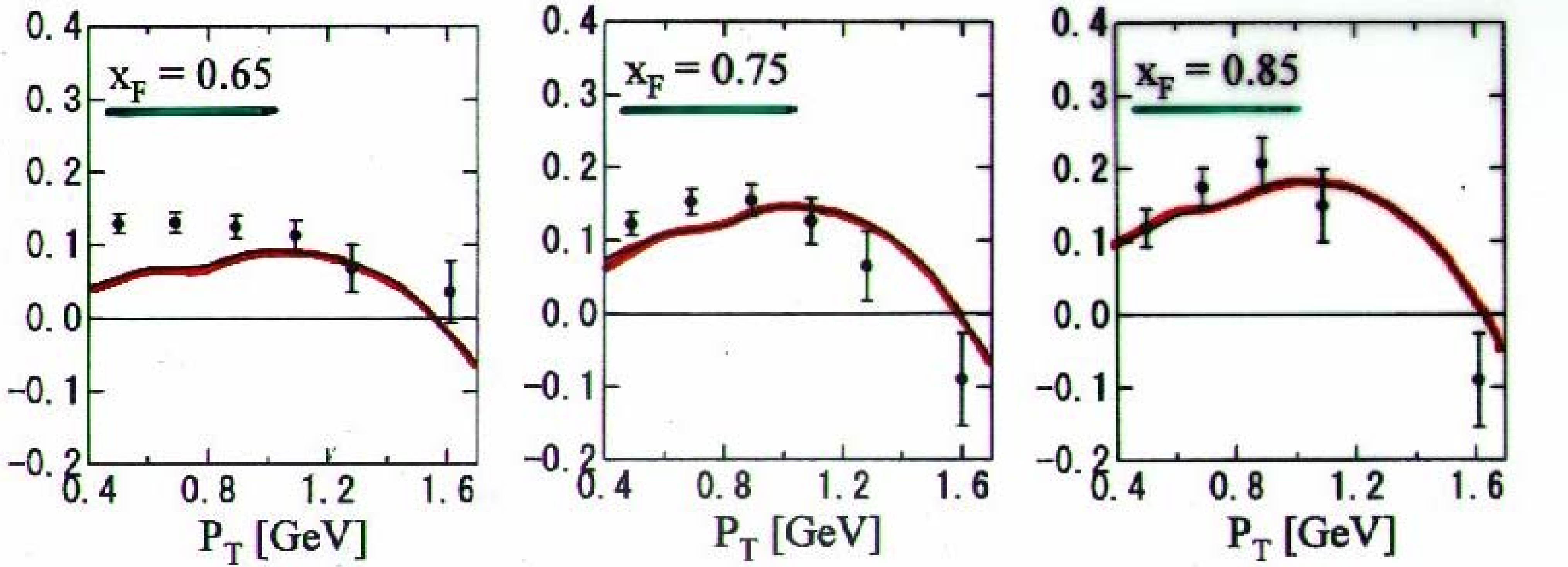
This correction depresses contribution of the Vector component.

Spin polarization; $\Sigma^- A \to \Lambda X$ at 340GeV/c





Spin polarization; $\Sigma^{-} A \rightarrow \Lambda X$ at 340GeV/c



Summary

- The inclusive hyperon productions, Spin polarizations.
- The Scalar and Vector diquarks contributing cases.
- In general, the Vector component has a too much predominance.

(1) The Schwinger mechanisms reduces it.

Well reproduces $P(p_t, x_F)$ for a wide p_t and x_F range.

(2) The form factor effect provides a similar role.