XIX Baldin ISHEPP
October 1, 2008

# Open Charm production in peripheral reactions:

$$\bar{p}p \to \bar{Y}_c Y_c' \qquad \bar{p}p \to D\bar{D} \qquad \bar{p}p \to D\bar{D}^*$$

## at PANDA-FAIR energy region with $\sqrt{s} \leq 15$ GeV

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PRC **78**, 025201 (2008)

# Talk Outline

1. Motivation
2. Model
3. Reactions $\bar{p}p \rightarrow \bar{\Lambda}\Lambda(\Sigma)$ and $\bar{p}p \rightarrow \bar{\Lambda}_c\Lambda_c(\Sigma_c)...$
4. Reactions $\bar{p}p \rightarrow \bar{K}K$ and $\bar{p}p \rightarrow D\bar{D}...$
5. Reactions $\bar{p}p \rightarrow \bar{K}K^*$ and $\bar{p}p \rightarrow D\bar{D}^*...$

(a) *differential cross section:* $\frac{d\sigma}{dt}$

(b) *longitudinal asymmetry:* $\mathcal{A} = \frac{d\sigma^A - d\sigma^P}{d\sigma^A + d\sigma^P},$

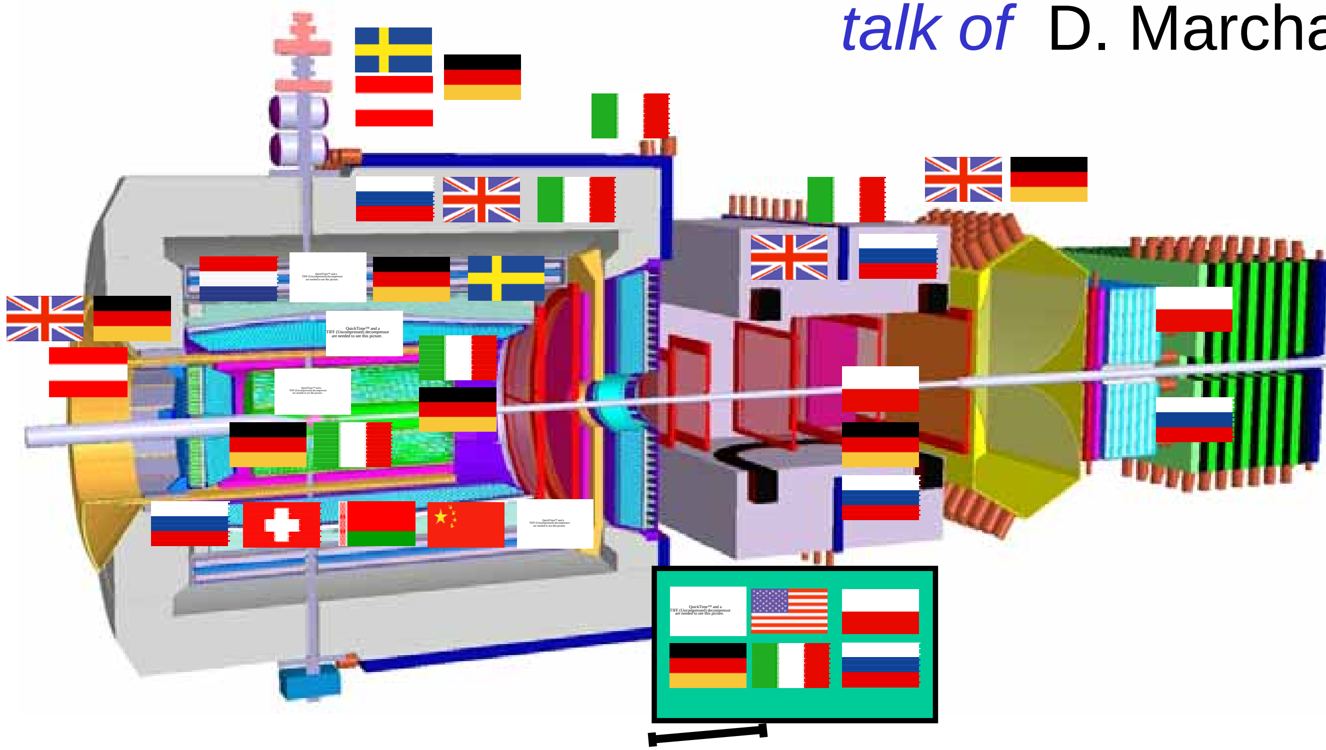
***where*** $d\sigma^A \equiv d\sigma^{\rightleftarrows}$ $d\sigma^P \equiv d\sigma^{\rightrightarrows}$

$s,\ t-$ ***dependence***

**Motivation:** ***Studying the Open Charm production is essential part of the International PANDA/FAIR project***

I. $\vec{\bar{p}}(3.5\text{GeV/c})+\vec{H}_2$ II. $\vec{\bar{p}}(15\text{GeV/c}) + \vec{p}(3.5\text{GeV/c})$

*talk of* D. Marchand, Oct. 4




***Our aim is quantitative estimation of the cross sections and asymmetries of the exclusive charm production just at forward production***

# Problems of “conventional” models

**pQCD models**: ***need large amount of gluons / sea quarks at x~1***

**Regge models**: ***(i) linear “charmed” trajectories with conventional baryon/meson slopes lead to negative intercepts with a large absolute value*** $\alpha(0) \sim -|4 \div 5|$

***(ii) Unknown energy scale parameter*** $\left(\frac{s}{s_0}\right)^{\alpha(t)}$

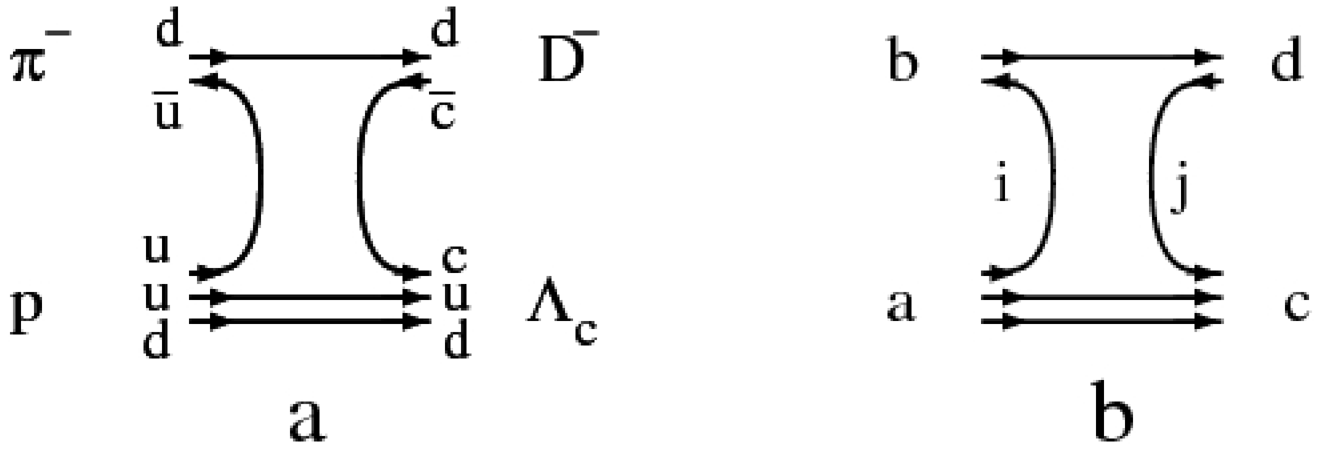
$$\sigma^{th}_{\pi^\pm N \to \Lambda_c X} \ll \sigma_{\pi^\pm N \to \Lambda_c X} \sim 3.4 \pm 1.1 \mu\text{b}$$
$$\text{at } \sqrt{s} \simeq 22 \text{ GeV}$$

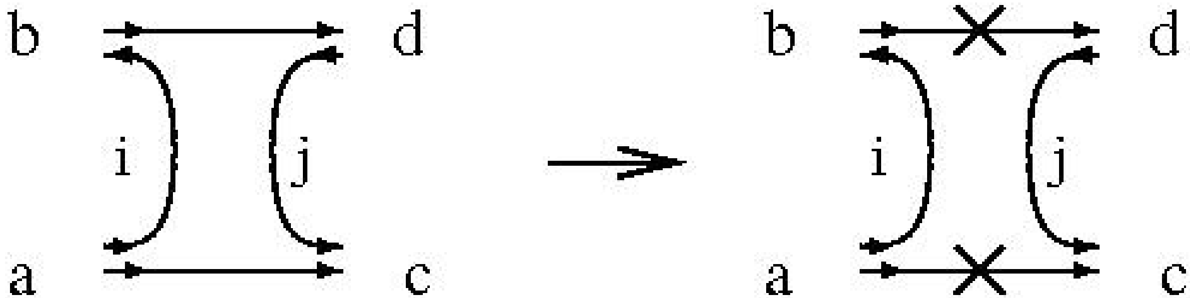
**Alves *et al* PRL 77, 2388 (1996)**

# Diffractive production in terms of the planar quark diagrams

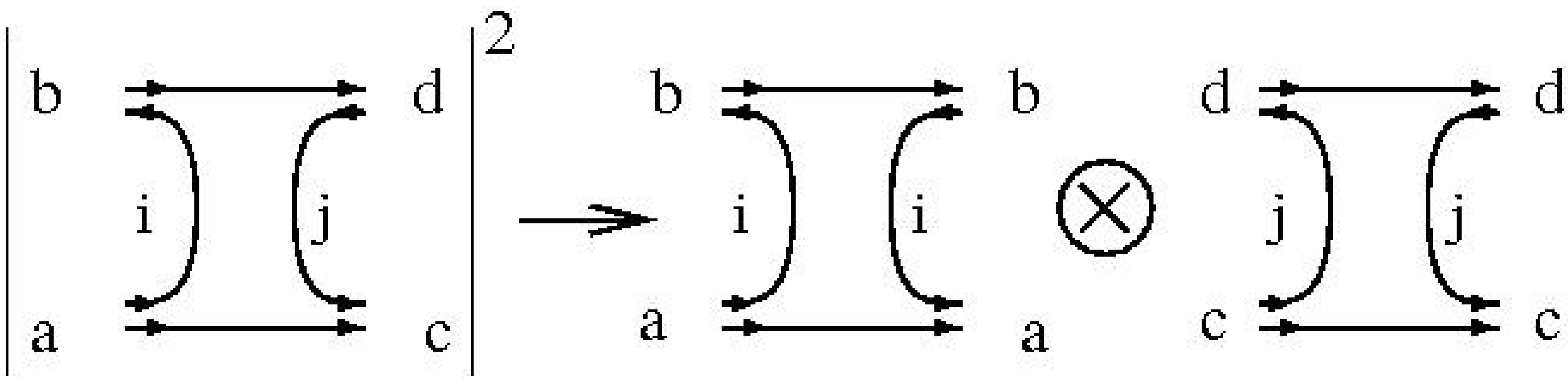
Kaidalov Z. Phys. C **12** (1982).

Boreskov&Kaidalov Sov.J.N.P. **37** (1983).






$$w^2_{ab\to cd} \simeq w_{ab\to ab} \times w_{cd\to cd}$$




$$T \sim \Gamma(1-\alpha_{ij}(t)) \left(-\frac{s}{s_{ij}}\right)^{\alpha_{ij}(t)-1}$$

# Equations for effective trajectory and energy scale parameter

$$w^2_{p\bar{p}\to\Lambda\bar{\Lambda}} \simeq w_{p\bar{p}\to p\bar{p}} \times w_{\Lambda\bar{\Lambda}\to\Lambda\bar{\Lambda}}$$

$$T \sim \Gamma(1-\alpha_{\bar{s}q}(t)) \left(-\frac{s}{s_{\bar{p}p:\bar{\Lambda}\Lambda}}\right)^{\alpha_{\bar{s}q}(t)-1}$$

- $2\alpha_{\bar{s}q}(0) = \alpha_{\bar{q}q}(0) + \alpha_{\bar{s}s}(0)$ ,
- $2/\alpha'_{\bar{s}q} = 1/\alpha'_{\bar{q}q} + 1/\alpha'_{\bar{s}s},$
- $\left(s_{\bar{p}p:\bar{\Lambda}\Lambda}\right)^{2(\alpha_{K^*}(0)-1)} =$

$$\left(s_{\bar{p}p}\right)^{\alpha_\rho(0)-1} \times \left(s_{\bar{\Lambda}\Lambda}\right)^{\alpha_\phi(0)-1} .$$

# Non-linear Regge trajectories (“diagonals”)

Brisudova, Burakovsky and Goldman PRD **61**, (2000).

$$\alpha(t) = \alpha(0) + \gamma(\sqrt{T} - \sqrt{T - t})$$

where $\gamma = 3.65\ \mathrm{GeV}^{-1}$ and $T >> 1\ \mathrm{GeV}^2$

In the diffractive region with $-t \ll T$,

$$\alpha(t) = \alpha(0) + \alpha' t$$

$$\alpha' = \gamma / 2\sqrt{T} \qquad \sqrt{T} \sim 2.5 \div 5.5\ \mathrm{GeV}$$

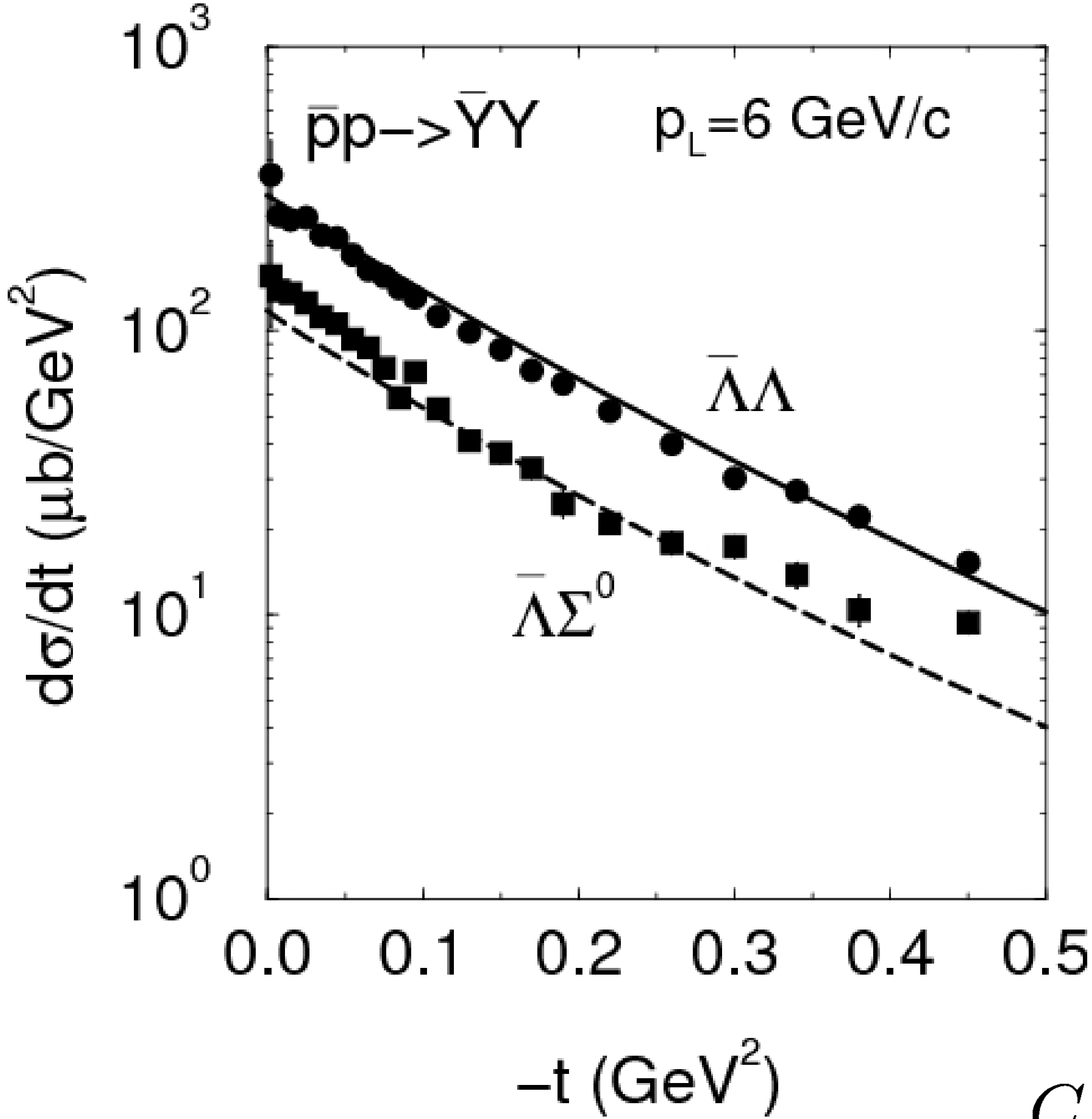
# Reaction $\bar{p}p \to \bar{Y}Y$, $Y = \Lambda, \Sigma, \Lambda_c, \Sigma_c \ldots$

$$T^{\bar{p}p\to\bar{\Lambda}\Lambda}_{m_f n_f; m_i, n_i} = C(t)\mathcal{M}^{\bar{p}p\to\bar{\Lambda}\Lambda}_{m_f n_f; m_i, n_i}(s,t)$$
$$\times \frac{g^2_{K^*N\Lambda}}{s_0}\Gamma(1-\alpha_{\bar{s}q}(t)) \left(-\frac{s}{s_{\bar{p}p:\bar{\Lambda}\Lambda}}\right)^{\alpha_{\bar{s}q}(t)-1}$$

$$\mathcal{L}_{K^*NY} = -\bar{Y}\left(\gamma_\mu K^{*\mu} - \frac{\kappa_{K^*NY}}{M_N+M_Y}\sigma_{\mu\nu}\partial^\nu K^{*\mu}\right) N + \text{h.c.} \ ,$$

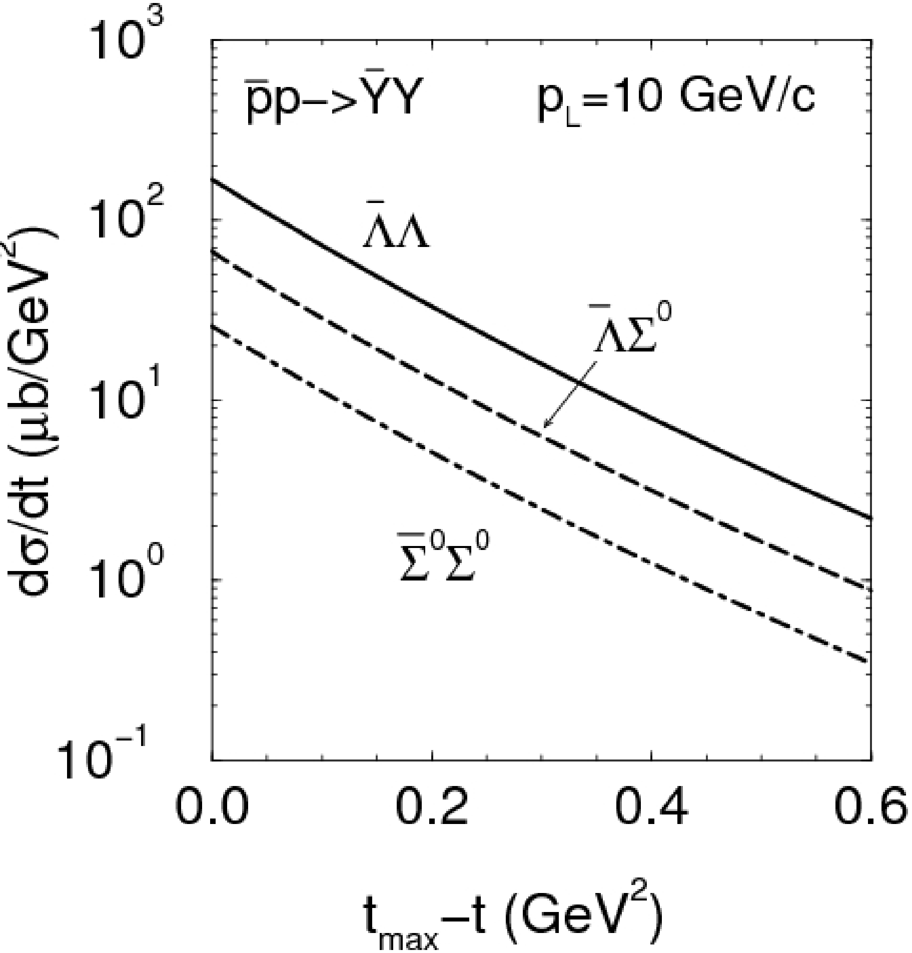
$g_{KNY}, g_{K^*NY}, \kappa_{K^*NY}$ - from hyper-nucleon physics

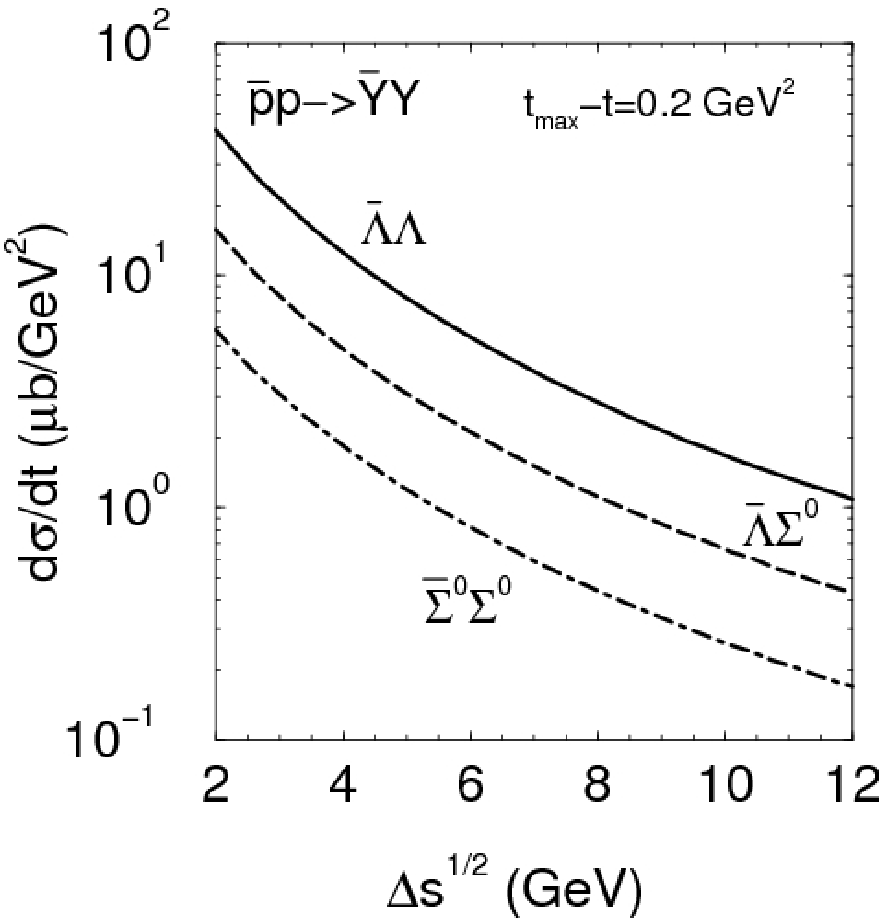
Nijmegen potential **Stoks & Rijken** PRC, **59**, 3009 ('99)



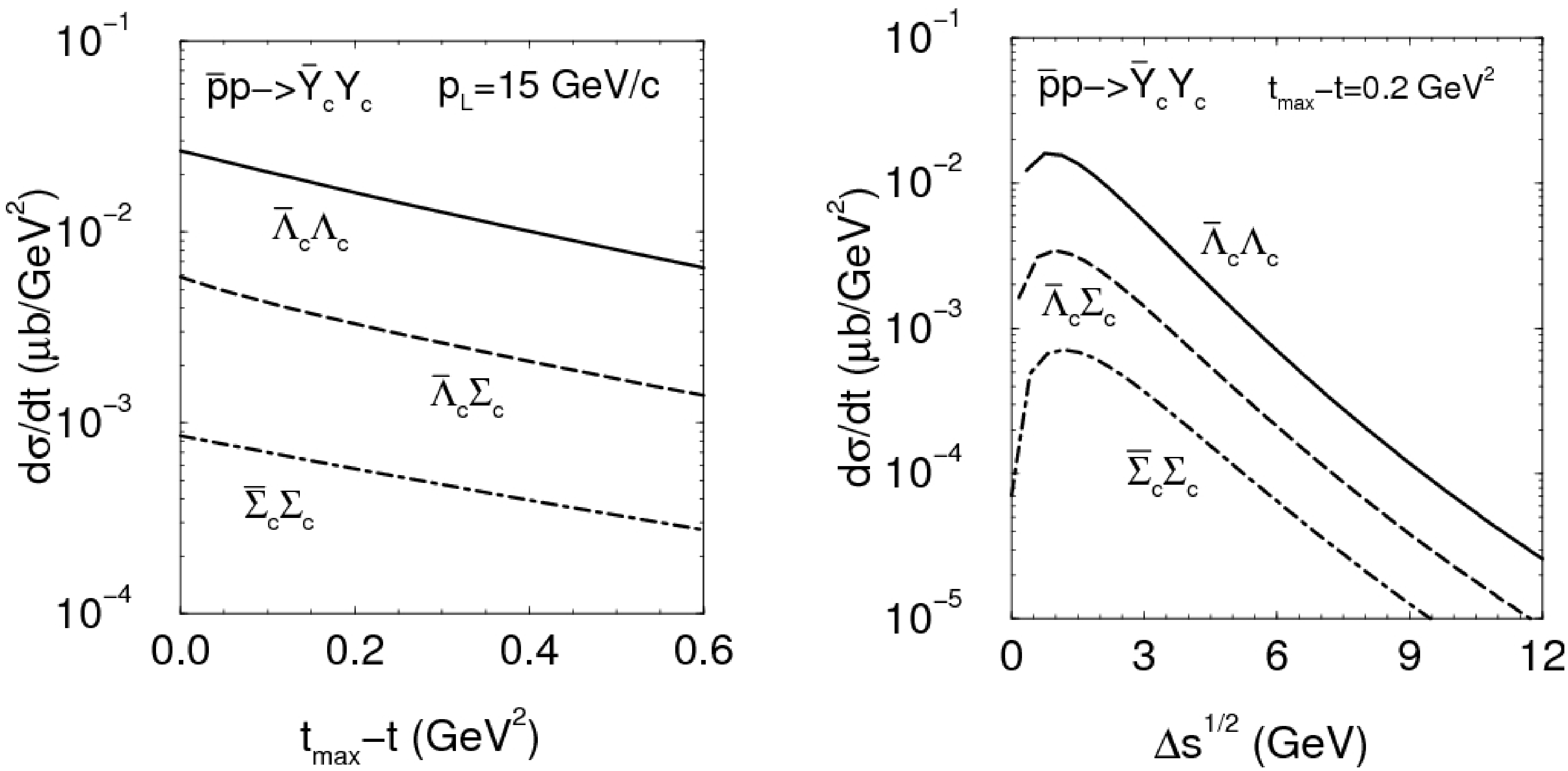

$$C(t) = \frac{0.38}{(1 - t/1.15)^2}$$

# Reaction $\bar{p}p \rightarrow \bar{Y}Y$, $Y = \Lambda, \Sigma^o$



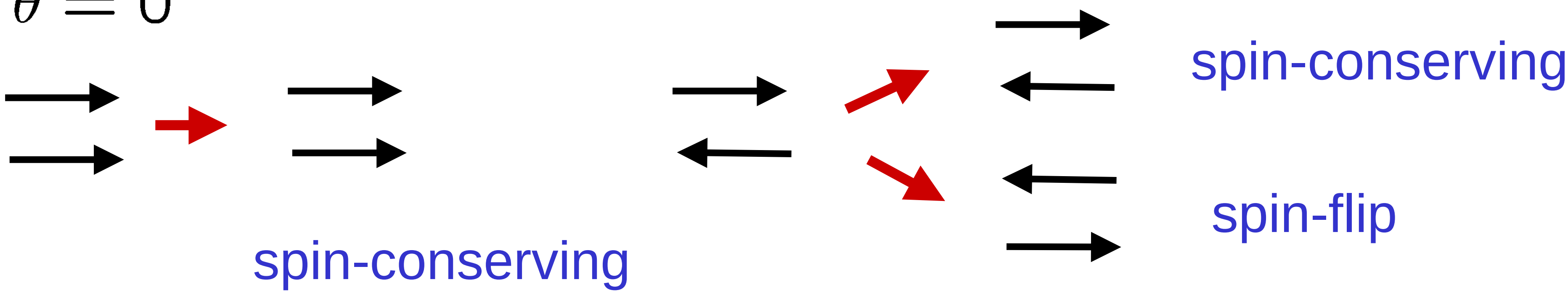
# Reaction $\bar{p}p \to \bar{Y}_c Y_c$, $Y = \Lambda_c^+, \Sigma_c^+$



# Longitudinal asymmetry

$$\mathcal{A} = \frac{d\sigma^A - d\sigma^P}{d\sigma^A + d\sigma^P}, \qquad d\sigma^A \equiv d\sigma^{\rightleftarrows}, \quad d\sigma^P \equiv d\sigma^{\rightrightarrows}$$

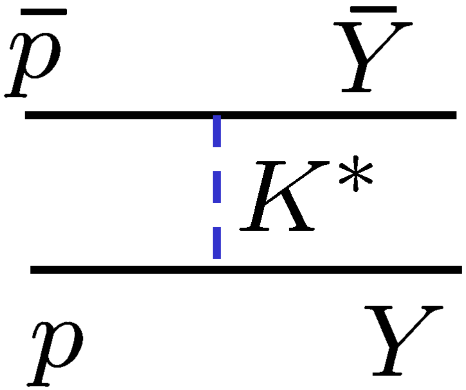
$\theta = 0$




$$T_{m_f n_f; m_i, n_i} \sim A(s)\, \delta_{m_i m_f}\, \delta_{n_i n_f} + \frac{1}{\sqrt{2}} B(s)\, (1 - 4 m_i m_f)\, \delta_{-m_i m_f} \delta_{-n_i n_f}$$

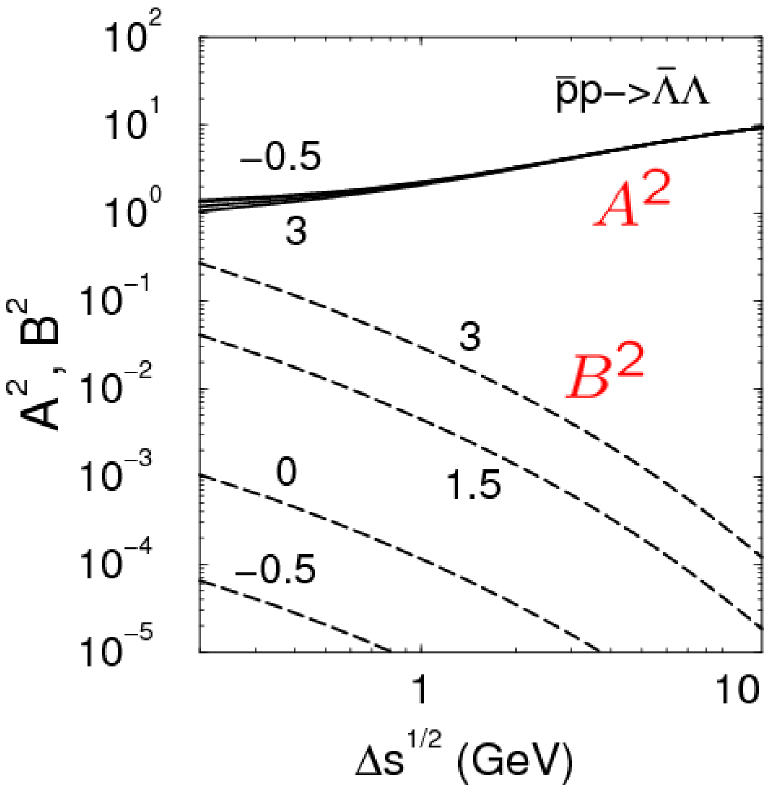
$$\boxed{\mathcal{A} = \frac{B^2(s)}{A^2(s) + B^2(s)}}$$

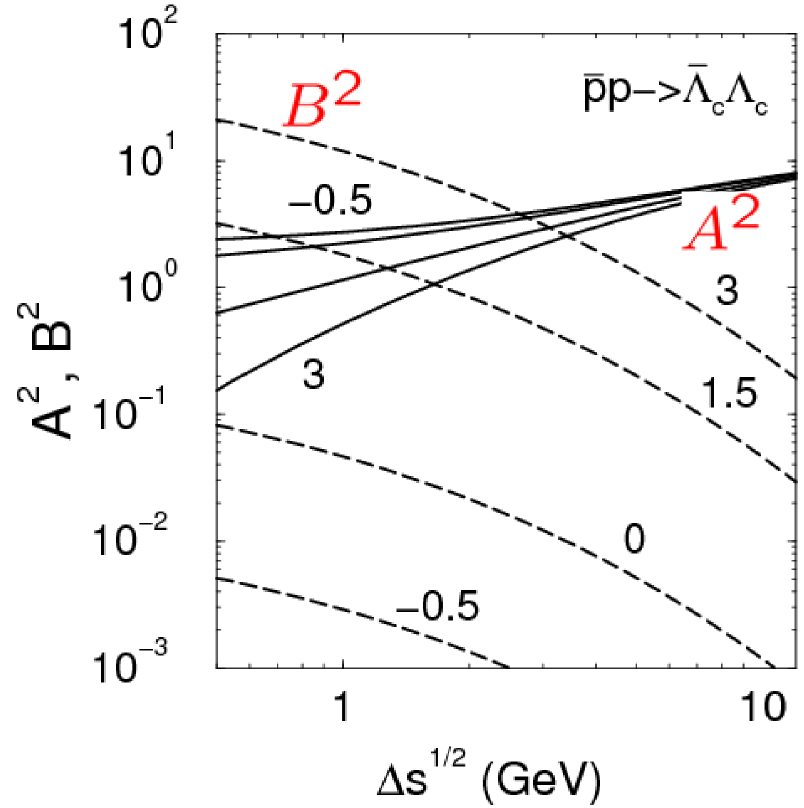
# Structure of spin-flip amplitude




$$B(s) = -\sqrt{2}\left((1+\kappa)(\frac{\mathbf{p}_p}{E+M_N} - \frac{\mathbf{p}_Y}{E+M_Y})\right)^2$$

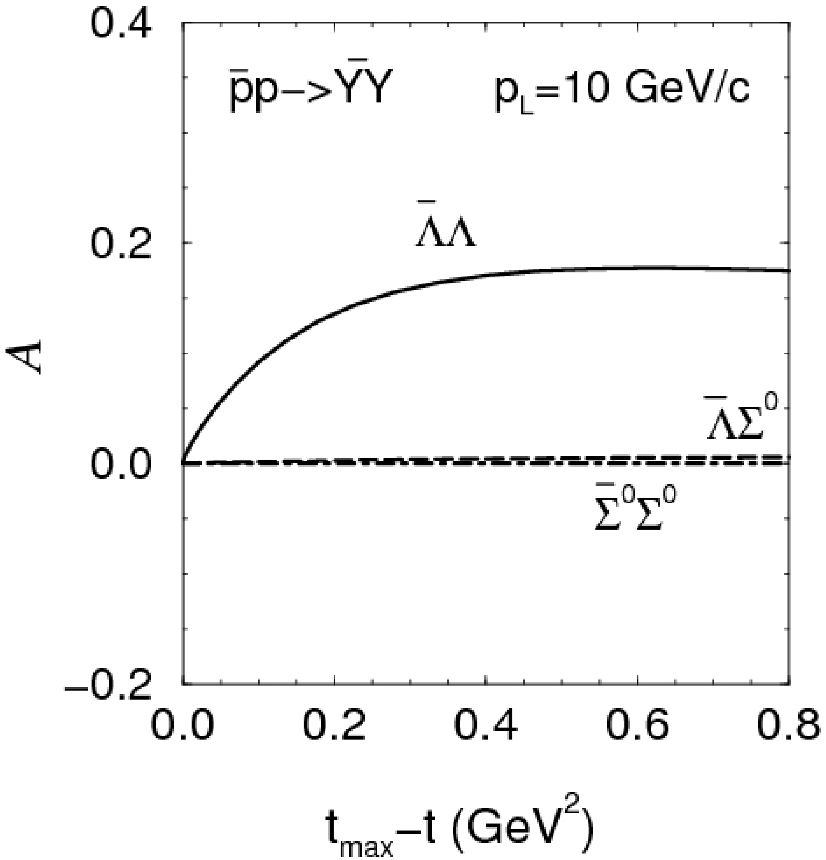
$$\mathcal{A} = \frac{B^2(s)}{A^2(s) + B^2(s)}$$

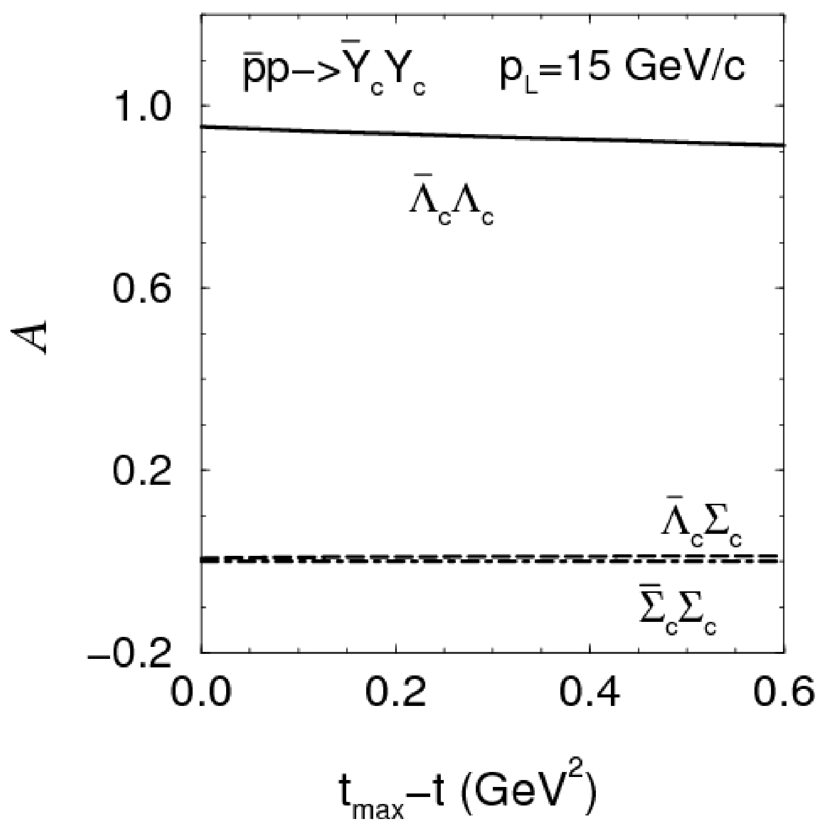


# *Asymmetry* *t-dependence*

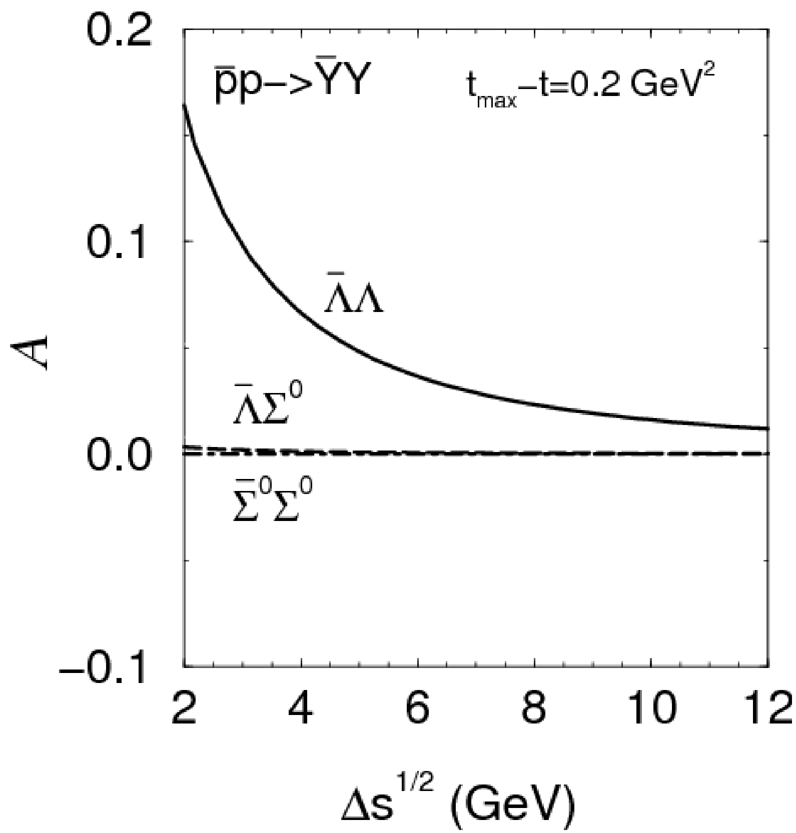
Reaction $\bar{p}p \to \bar{Y}Y$ , $Y = \Lambda, \Lambda_c^+, \Sigma^o, \Sigma_c^+$

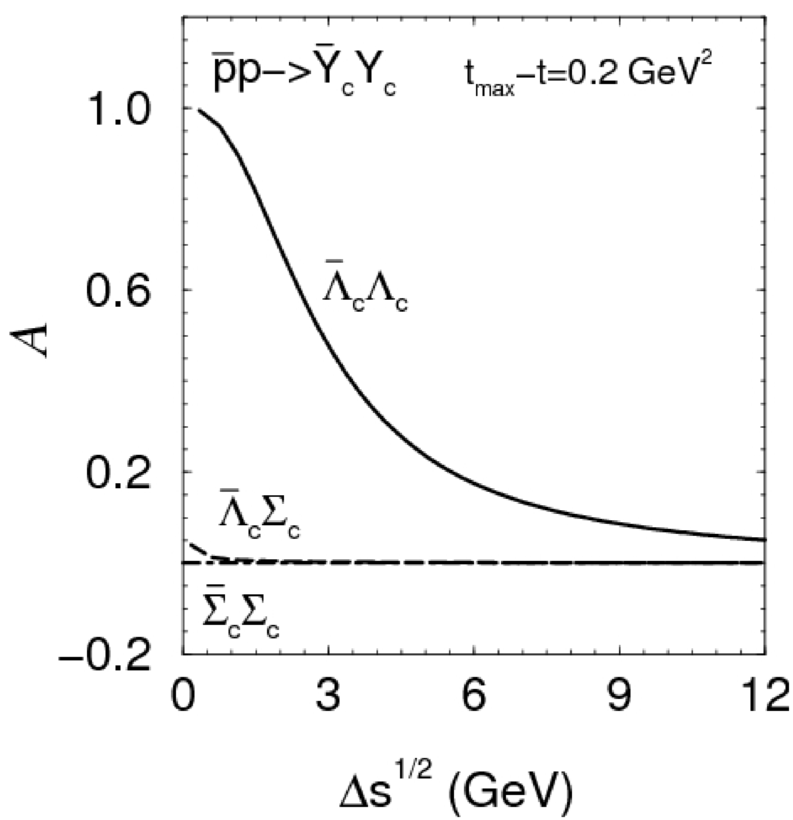


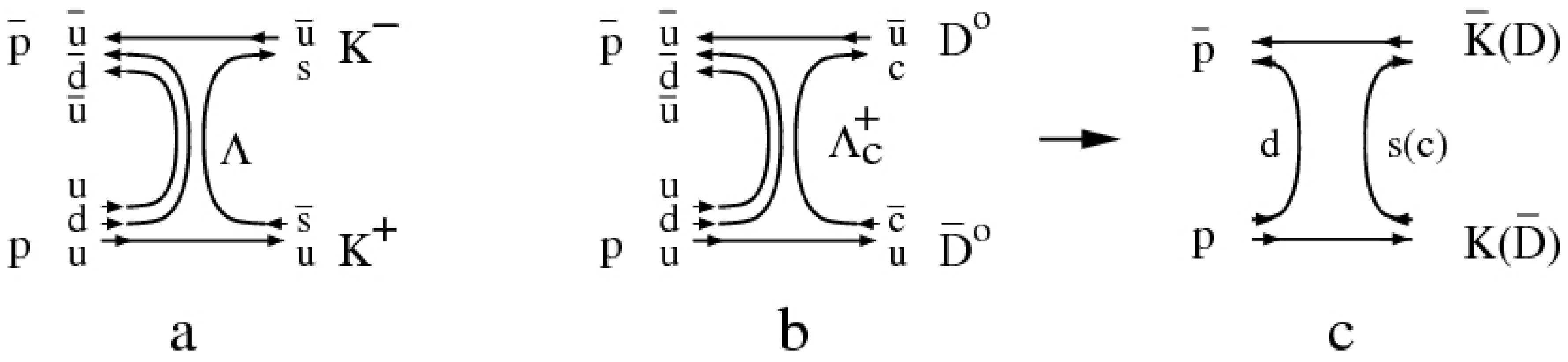
# *Asymmetry* *s-dependence*

Reaction $\bar{p}p \rightarrow \bar{Y}Y$ , $Y = \Lambda, \Lambda_c^+, \Sigma^o, \Sigma_c^+$



# Reaction $\bar{p}p \to \bar{K}K\,(D\bar{D})$

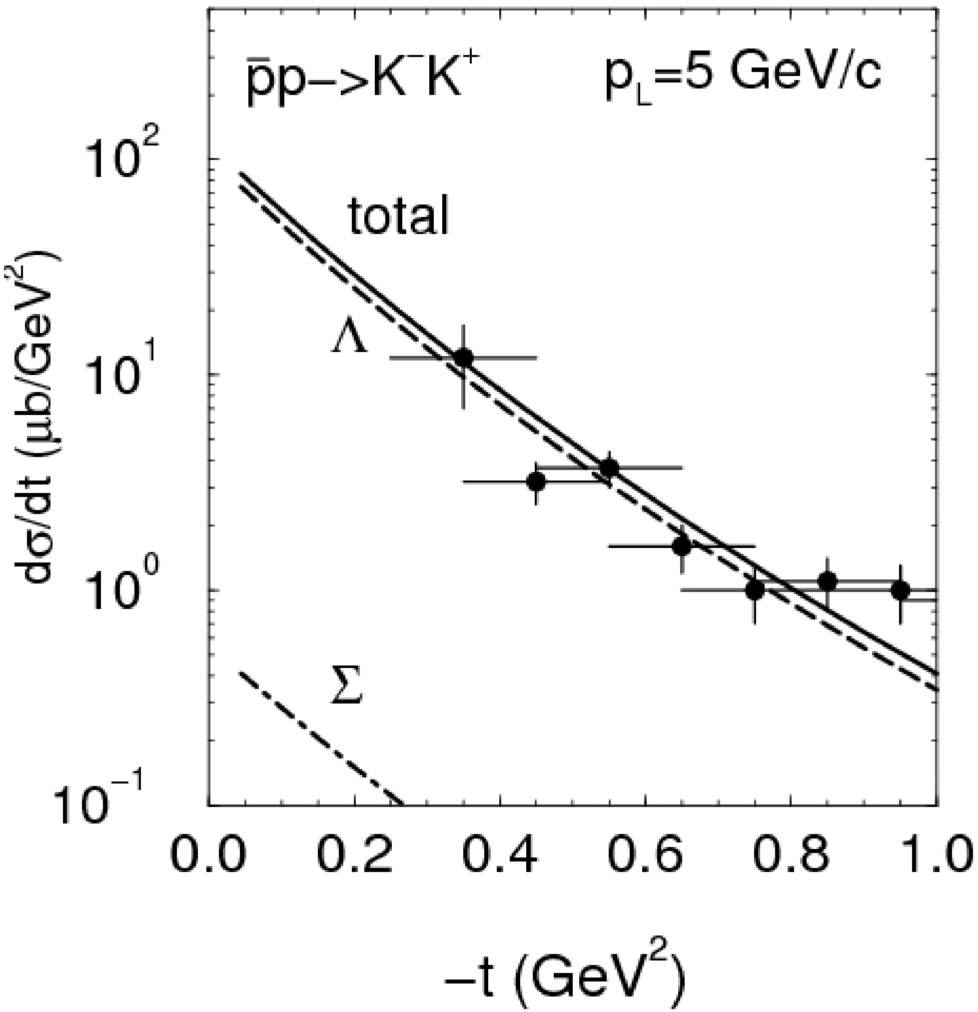



$$\mathcal{L}_{NYK} = -i\bar{N}\gamma_5 YK + \text{h.c.}\ ,$$

$$
\begin{aligned}
2\alpha_{sd}(0) &= \alpha_{\bar{s}s}(0) + \alpha_{\bar{d}d}(0)\ , \\
2/\alpha'_{sd} &= 1/\alpha'_{\bar{s}s} + 1/\alpha'_{\bar{d}d}
\end{aligned}
$$

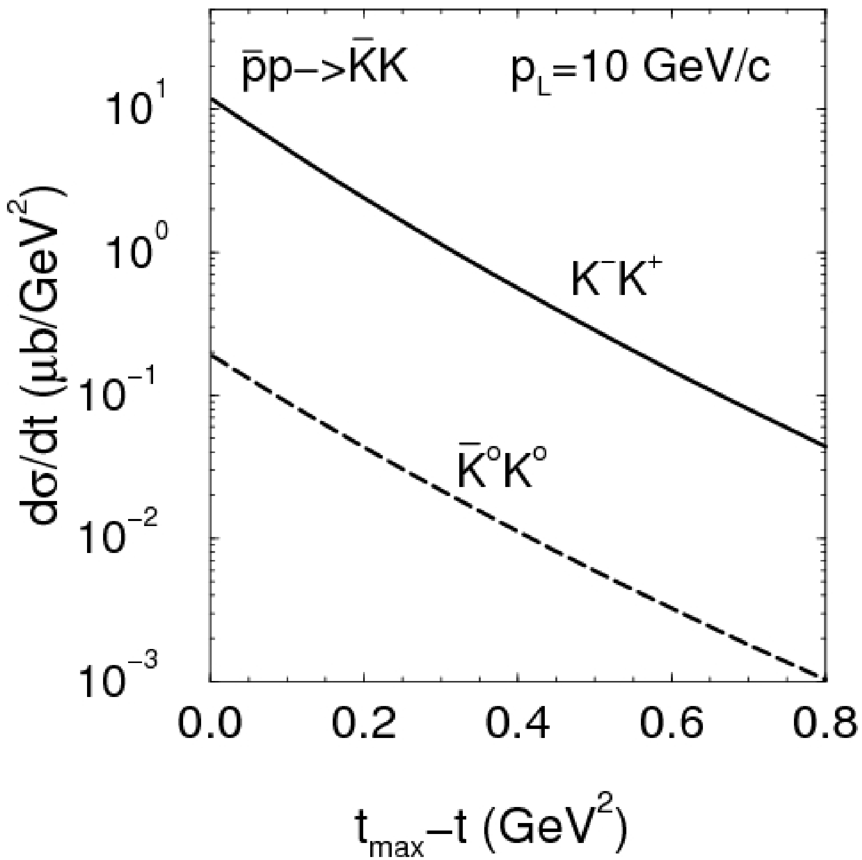
$\alpha_{sd}(t) \equiv \alpha_{\Lambda}(t)$ - input

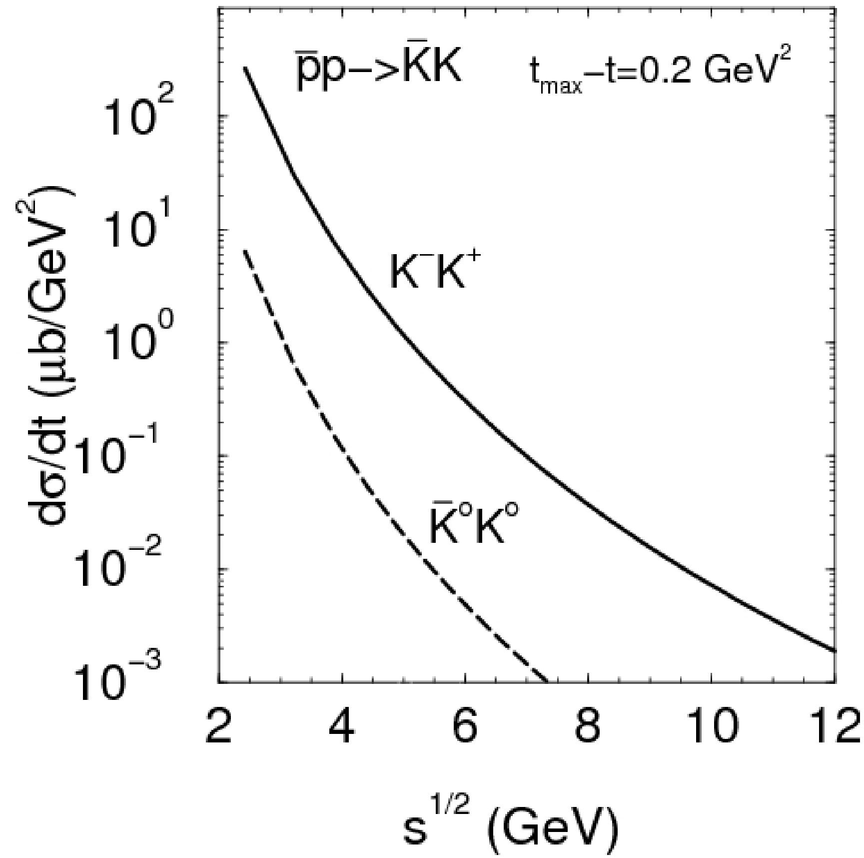
$$
\left(s_{\bar{p}p:\bar{K}K}\right)^{2(\alpha_{\Lambda}(0)-\frac{1}{2})} = \left(s_{\bar{K}K}\right)^{\alpha_{\phi}(0)-1} \times \left(s_{\bar{p}p}\right)^{\alpha_{\bar{d}d}(0)} .
$$



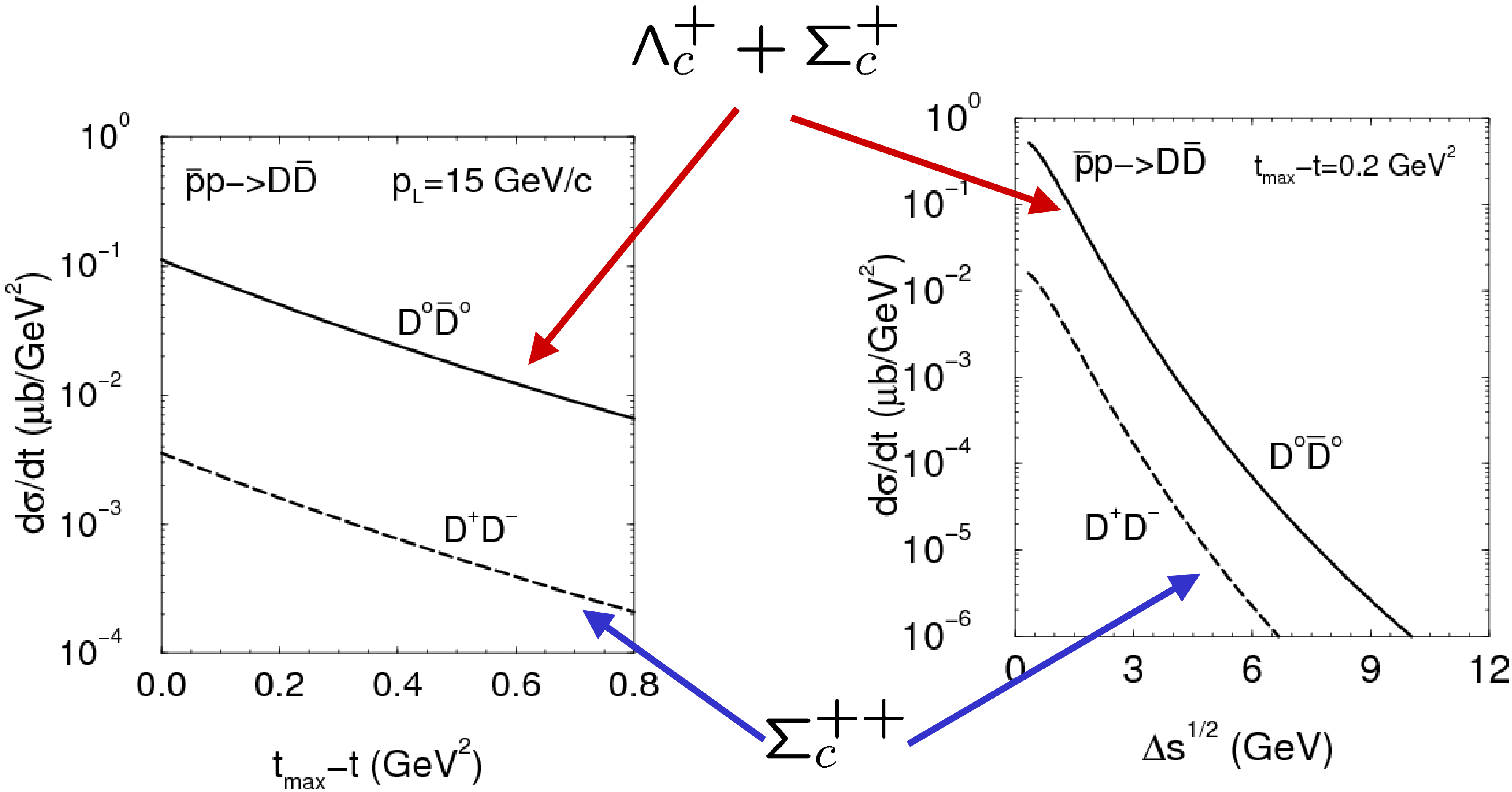

$$C(t) = \frac{0.51}{(1 - t/1.15)^2}$$

# Reaction $\bar{p}p \rightarrow \bar{K}K$



# Reaction $\bar{p}p \to D\bar{D}$



# Longitudinal asymmetry

$$\bar{p}p \rightarrow \bar{K}K\,(D\bar{D})$$

$\theta = 0$

$J_{\text{final}} = 0$

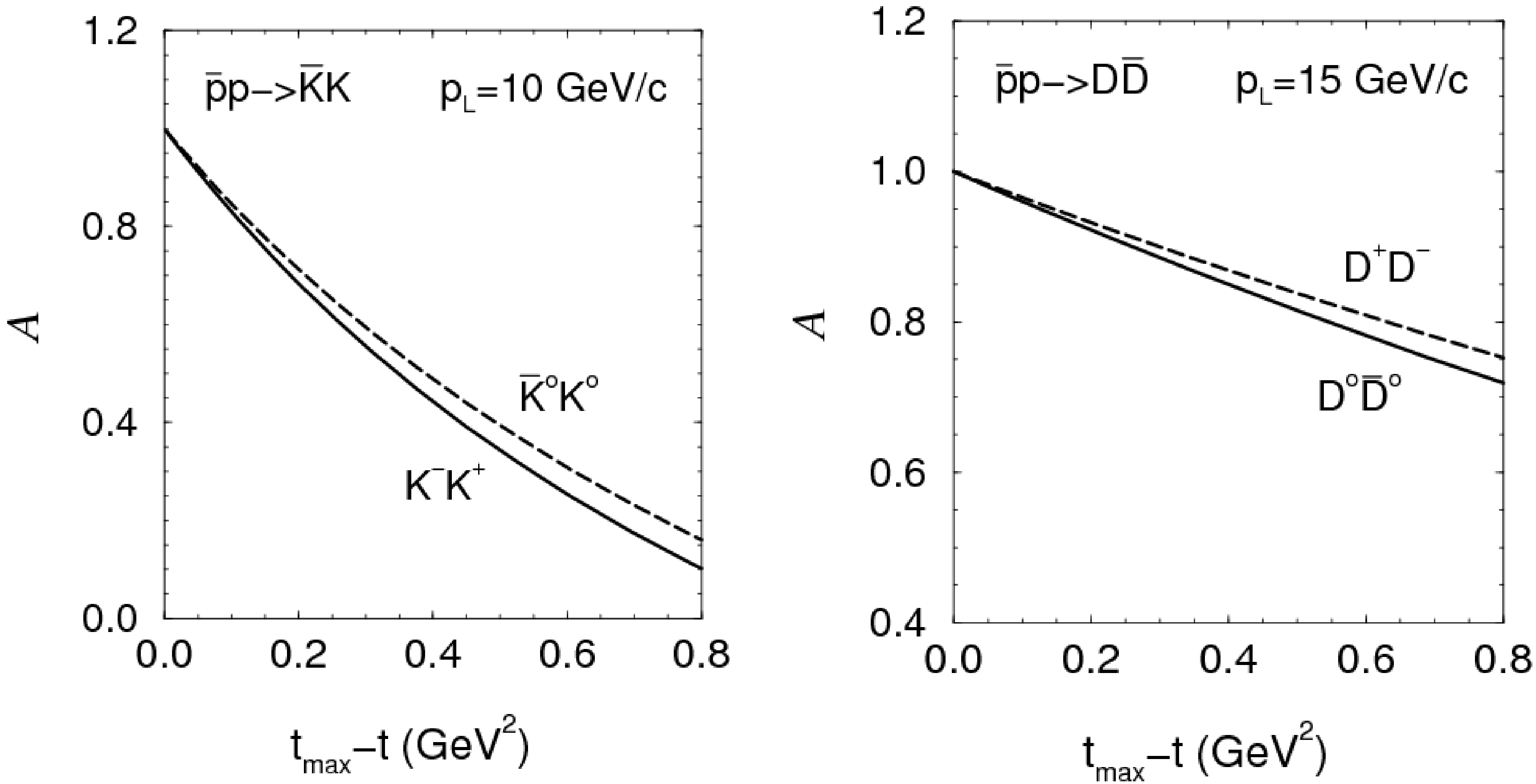

$$\mathcal{A} = \frac{d\sigma^A - d\sigma^P}{d\sigma^A + d\sigma^P},$$

$$d\sigma^P \equiv d\sigma^{\rightrightarrows} \simeq 0$$

$$\mathcal{A} \simeq 1$$

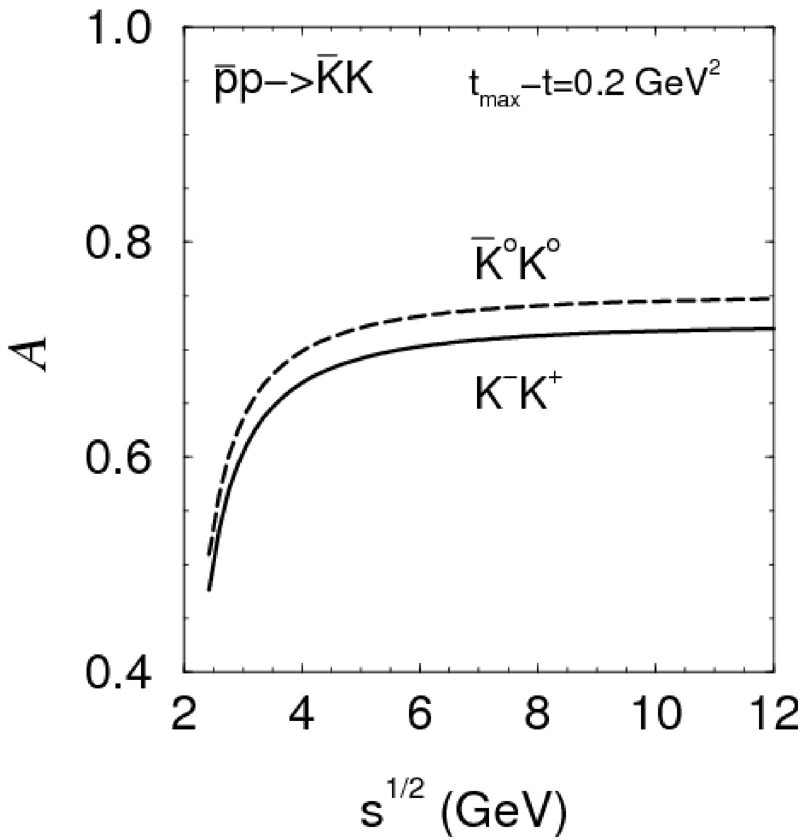
# ***Asymmetry*** *t-dependence*

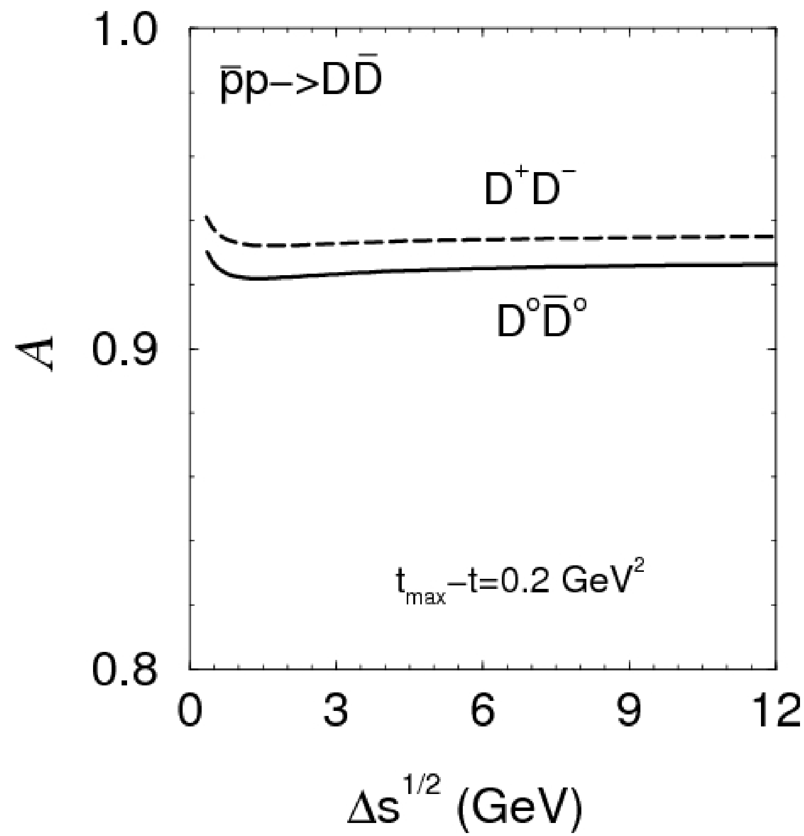
Reactions $\bar{p}p \to \bar{K}K,\ D\bar{D}$



# *Asymmetry* *s-dependence*

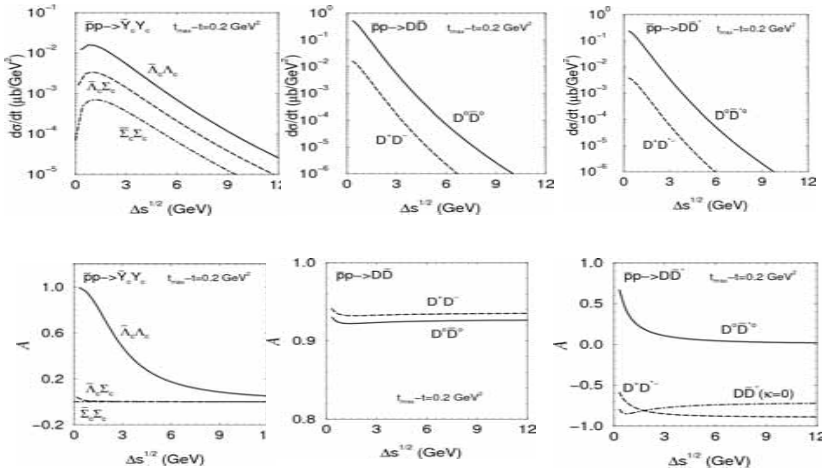
## Reactions $\bar{p}p \to \bar{K}K,\ D\bar{D}$



# Summary

- We have evaluated the cross sections and longitudinal asymmetries for $\bar{p}p \to \bar{Y}_c Y_c,\ D\bar{D},\ D^*\bar{D},\ \ldots$ reaction at $\sqrt{s} \le 15$ GeV



- This result may be used in design of PANDA detector
- And further development of the theoretical approaches