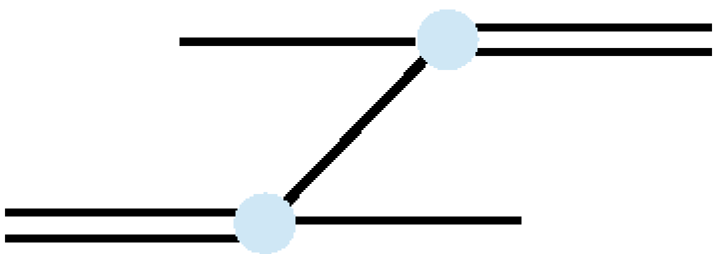
N.B. Ladygina

STUDY OF DEUTERON-PROTON BACKWARD ELASTIC SCATTERING AT INTERMEDIATE ENERGIES

- $dp \to dp$ reaction is considered in backward kinematics at the scattering angles $\theta^* \geq 140^0$.
- The theoretical model is suggested for description of both differential cross section and polarization observables in the deuteron energy range between 500 and 2000 MeV.
- The calculation results are presented in comparison with the data.

$dp \to dp$ ONE



$$T_{20} = \frac{1}{\sqrt{2}} \frac{\sqrt{8}u(p_0)w(p_0) - w^2(p_0)}{u^2(p_0) + w^2(p_0)}$$

$$\kappa = \frac{u^2(p_0) - w^2(p_0) - u(p_0)w(p_0)/\sqrt{2}}{u^2(p_0) + w^2(p_0)}$$

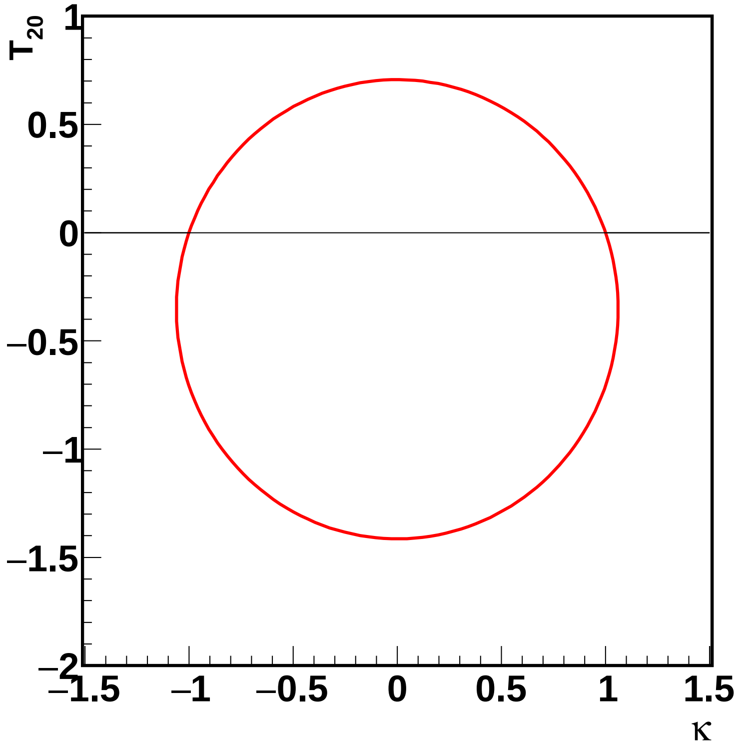
T_{20} – **tenzor analyzing power**

κ – **vector polarisation transfer from the initial deuteron to the final proton**

$u(p_0)$, $w(p_0)$ – **S- and D-components of the deuteron wave function**

T_{20} vs κ

Turn out that in ONE T_{20} and κ are related as a circle of radius $3\sqrt{8}$ (B. Kuehn, CF.Perdrisat and E.A. Strokovsky, JINR, Dubna preprint El- 95-7 (1995))



$$\left(T_{20} + \frac{1}{2\sqrt{2}}\right)^2 + \kappa^2 = \frac{9}{8}$$

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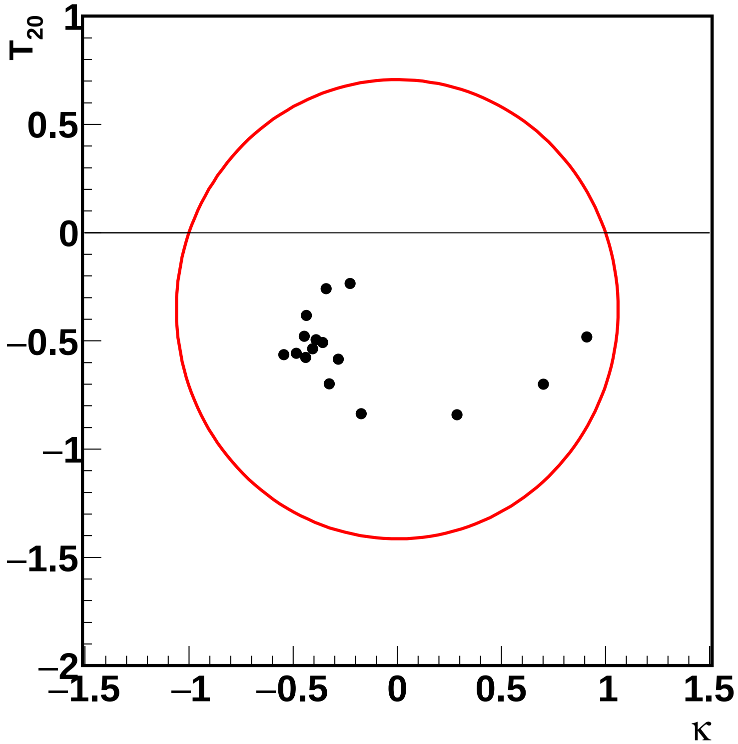
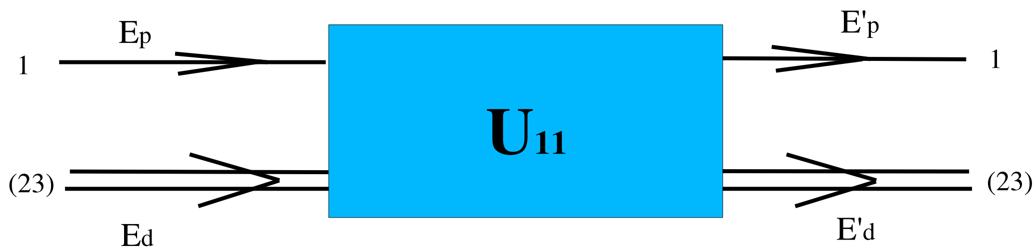


$$\left(T_{20} + \frac{1}{2\sqrt{2}}\right)^2 + \kappa^2 = \frac{9}{8}$$

- **-V.Punjabi et al. Phys.Lett. B350 (1995) 178**

$dp \to dp$



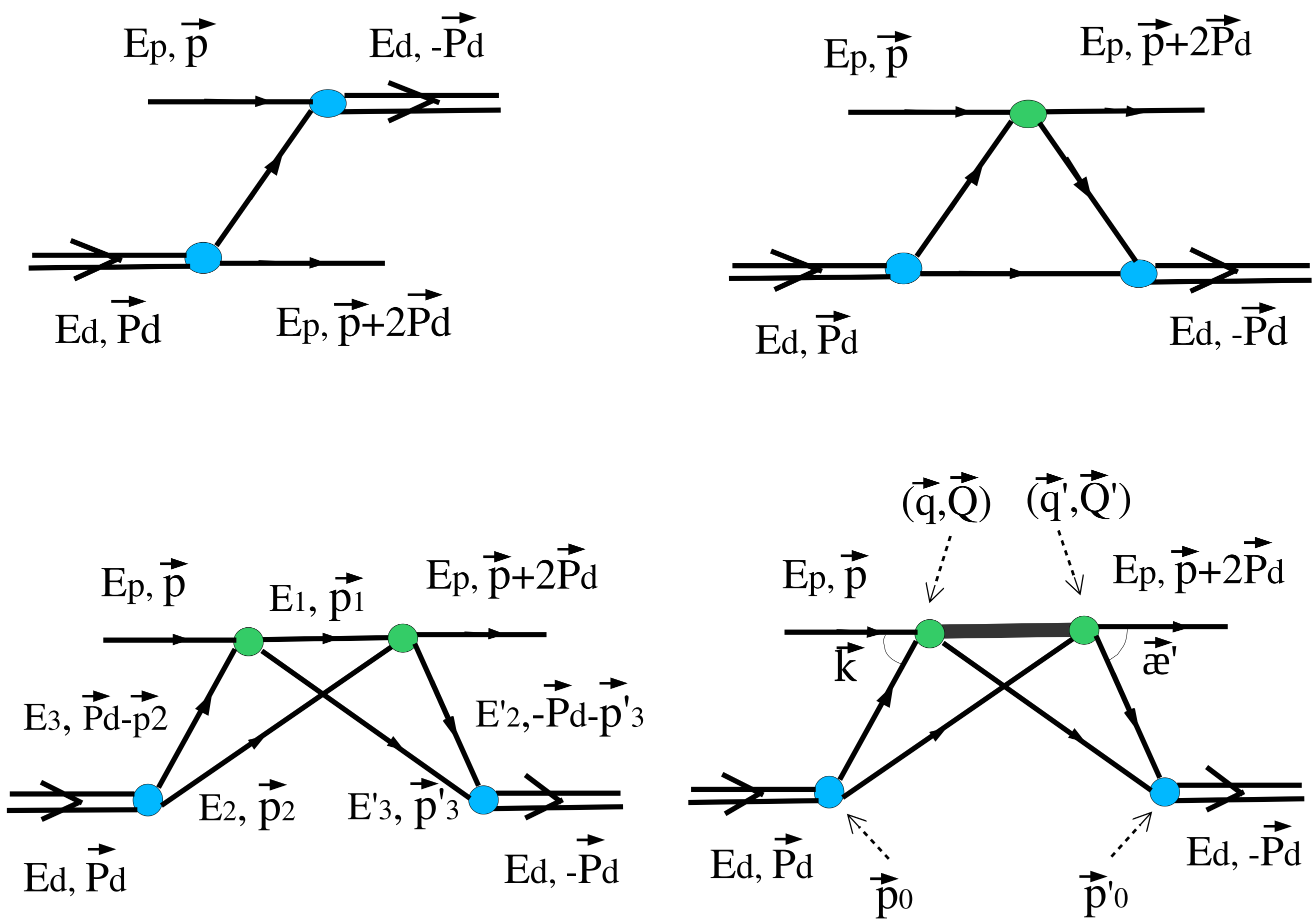
The matrix element of the transition operator U_{11} defines reaction amplitude

$$U_{dp\to dp} = \delta(E_d + E_p - E'_d - E'_p)\mathcal{J} =< 1(23)|[1 - P_{12} - P_{13}]U_{11}|1(23) >$$

Alt-Grassberger-Sandhas equations for rearrangement operators:

$$\begin{aligned} U_{11} &= t_{13}g_0U_{21} + t_{12}g_0U_{31} \\ U_{21} &= g_0^{-1} + t_{23}g_0U_{11} + t_{12}g_0U_{31} \\ U_{31} &= g_0^{-1} + t_{23}g_0U_{11} + t_{13}g_0U_{21} \end{aligned}$$

Diagrams



Ep, p
Ed, -Pd
Ed, Pd
Ep, p+2Pd
Ep, p
Ep, p+2Pd
Ed, Pd
Ed, -Pd
Ep, p
E1, p1
Ep, p+2Pd
E3, Pd-p2
E'2,-Pd-p'3
E2, p2
E'3, p'3
Ed, Pd
Ed, -Pd
(q,Q)
(q',Q')
Ep, p
Ep, p+2Pd
k
æ'
Ed, Pd
Ed, -Pd
p0
p'0

Contributions into the reaction

Iterating AGS-equations up to second order terms over t one obtains

$$\mathcal{J}_{dp\to dp} = \mathcal{J}_{ONE} + \mathcal{J}_{SS} + \mathcal{J}_{DS} + \mathcal{J}_{\Delta}$$

One-Nucleon-Exchange

$$\mathcal{J}_{ONE} = -2 < 1(23)|P_{12}g_0^{-1}|1(23) >$$

Single-Scattering

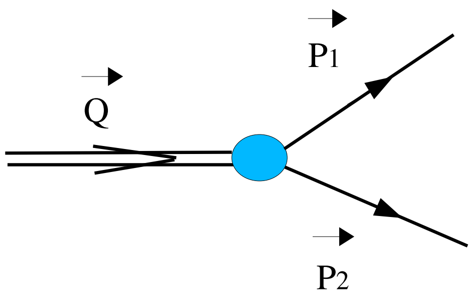
$$\mathcal{J}_{SS} = 2 < 1(23)|t_{12}^{sym}|1(23) >$$

Double-Scattering

$$\mathcal{J}_{DS} = 2 < 1(23)|t_{12}^{sym}g_0 t_{13}^{sym}|1(23) >,$$

$t_{ij}^{sym} = [1 - P_{ij}]t_{ij}$– **antisymmetrized NN-matrix.**

Lorenz transformation



$$L(\vec{u})p_1 = (E^*, \vec{p})$$
$$L(\vec{u})p_2 = (E^*, -\vec{p})$$

with velocity

$$\vec{u} = \frac{\vec{p}_1 + \vec{p}_2}{E_1 + E_2}$$

The c.m. energy of one of the nucleons E^* is related with Mandelstam variable s by

$$E^* = \sqrt{s}/2 \quad .$$

Let's introduce new variables $\vec{Q}$ and $\vec{k}$ which can be expressed through $\vec{p}_1$ and $\vec{p}_2$

$$\vec{Q} = \vec{p}_1 + \vec{p}_2$$
$$\vec{k} = \frac{(E_2 + E^*)\vec{p}_1 - (E_1 + E^*)\vec{p}_2}{E_1 + E_2 + 2E^*} \quad .$$

Deuteron wave function

The deuteron wave function in the rest has the standard form

$$< m_p m_n | \Omega_d | \mathcal{M}_d >= \frac{1}{\sqrt{4\pi}} < m_p m_n | \left\{ u(k) + \frac{w(k)}{\sqrt{8}} [3(\vec{\sigma}_1 \hat{k})(\vec{\sigma}_2 \hat{k}) - (\vec{\sigma}_1 \vec{\sigma}_2)] \right\} | \mathcal{M}_d >$$

$u(k)$ **and** $w(k)$ **-** $S-$ **and** $D-$ **components of the deuteron.**
Then the deuteron wave function in the moving frame is

$$< \vec{p}_1 \ \vec{p}_2, m_1 m_2 | \Omega_d | \vec{Q}, \mathcal{M}_d > \quad \sim \quad < \vec{k} \vec{Q}, m_1' m_2' | W^{\dagger}_{1/2}(\vec{p}_1, \vec{u}) W^{\dagger}_{1/2}(\vec{p}_2, \vec{u}) \Omega_d | \vec{0}, \mathcal{M}_d >$$

Nucleon-Nucleon t-matrix

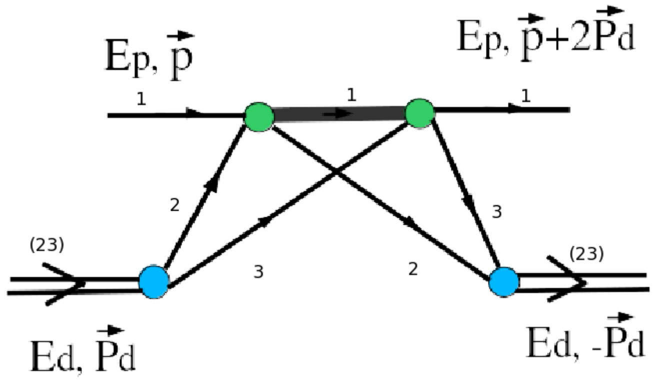
W.G.Love, M.A.Franey, Phys.Rev.C24, 1073 (1981)
N.B.Ladygina,nucl-th/0805.3021

$$< \kappa' m_1' m_2' | t | \kappa m_1 m_2 > \;=\; < \vec{\kappa}' m_1' m_2' | A + B(\vec{\sigma}_1 \hat{N}^*)(\vec{\sigma}_2 \hat{N}^*) + C(\vec{\sigma}_1 + \vec{\sigma}_2) \cdot \hat{N}^* + D(\vec{\sigma}_1 \hat{q}^*)(\vec{\sigma}_2 \hat{q}^*) + F(\vec{\sigma}_1 \hat{Q}^*)(\vec{\sigma}_2 \hat{Q}^*) | \vec{\kappa} m_1 m_2 >$$

where the orthonormal basis is combinations of the nucleons relative momenta in the initial $\vec{\kappa}$ and final $\vec{\kappa}'$ states

$$\hat{q}^* = \frac{\vec{\kappa} - \vec{\kappa}'}{|\vec{\kappa} - \vec{\kappa}'|} \quad , \quad \hat{Q}^* = \frac{\vec{\kappa} + \vec{\kappa}'}{|\vec{\kappa} + \vec{\kappa}'|} \quad , \quad \hat{N}^* = \frac{\vec{\kappa} \times \vec{\kappa}'}{|\vec{\kappa} \times \vec{\kappa}'|}$$

Δ-contribution



$$\mu^2 = E_\Delta^2 - \vec{p}_\Delta^{\,2}$$

Δ-contribution is defined by two $N\Delta$ matrices

$$\begin{aligned}\mathcal{J}_\Delta = \quad & < 1(23)|[1-P_{12}]|t_{N\Delta}|\Delta(1)N(2) > |N(3) > g_0 \\ & < N(2)| < \Delta(1)N(3)|t_{\Delta N}[1-P_{13}]|(23)1 >\end{aligned}$$

g_0–a free three-particle propagator:

$$g_0 = \frac{1}{E - E_2 - E_3' - E_\Delta - i\Gamma(E_\Delta)/2}$$

the distribution function of Δ-energy:

$$\rho(\mu) = \frac{1}{2\pi}\frac{\Gamma(\mu)}{(E_\Delta(\mu) - E_\Delta(m_\Delta))^2 + \Gamma^2(\mu)/4},$$

and wave functions of the initial and final deuterons.

Δ-isobar definition

The potential for the $NN \to N\Delta$ transition is based on the $\pi-$ and $\rho-$ exchanges:

$$t_{N\Delta}^{(\pi)} = -\frac{f_\pi f_\pi^*}{m_\pi^2} F_\pi^2(t) \frac{q^2}{m_\pi^2 - t} (\vec{\sigma} \cdot \hat{q})(\vec{S} \cdot \hat{q})(\vec{\tau} \cdot \vec{T})$$

$$t_{N\Delta}^{(\rho)} = -\frac{f_\rho f_\rho^*}{m_\rho^2} F_\rho^2(t) \frac{q^2}{m_\rho^2 - t} \{(\vec{\sigma}\vec{S}) - (\vec{\sigma} \cdot \hat{q})(\vec{S} \cdot \hat{q})\}(\vec{\tau} \cdot \vec{T})$$

with coupling constants:

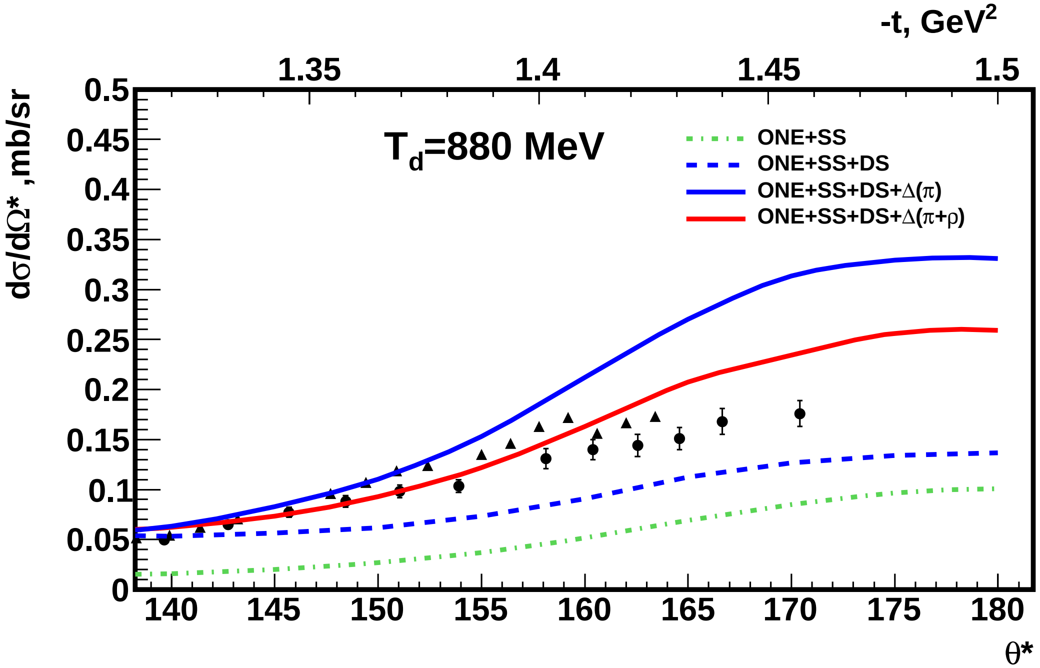
$$f_\pi = 1.008 \qquad f_\pi^* = 2.156$$

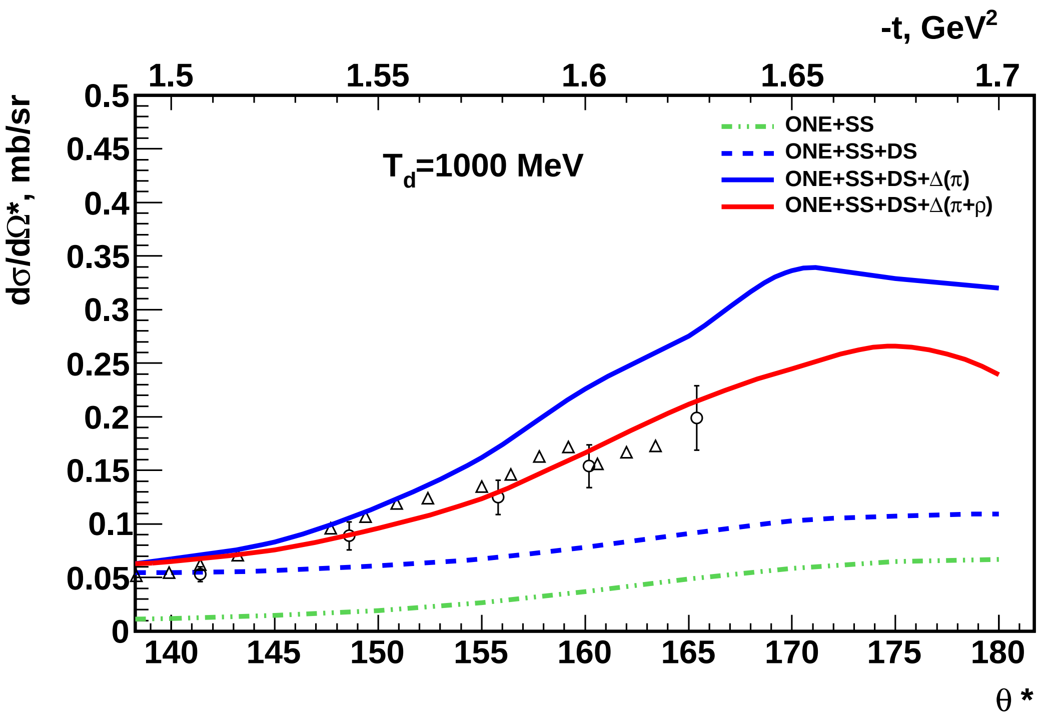
$$f_\rho = 7.8 \qquad f_\rho^* = 1.85 f_\rho$$

The hadronic form factor has a pole form:

$$F_x(t) = (\Lambda_x^2 - m_x^2)/(\Lambda_x^2 - t)^n, \quad n = 1 \quad for\ \pi - meson$$

$$n = 2 \quad for\ \rho - meson$$





○ - N.E.Booth et al., Phys.Rev.D4, p.1261 (1971), $T_d = 850 MeV$
△- J.C.Alder et al., Phys.Rev.C6, p.2010 (1972), $T_d = 940 MeV$

○-J.S.Vincent, Phys.Rev.Lett. 24, p.236 (1970), $T_d = 1169 MeV$
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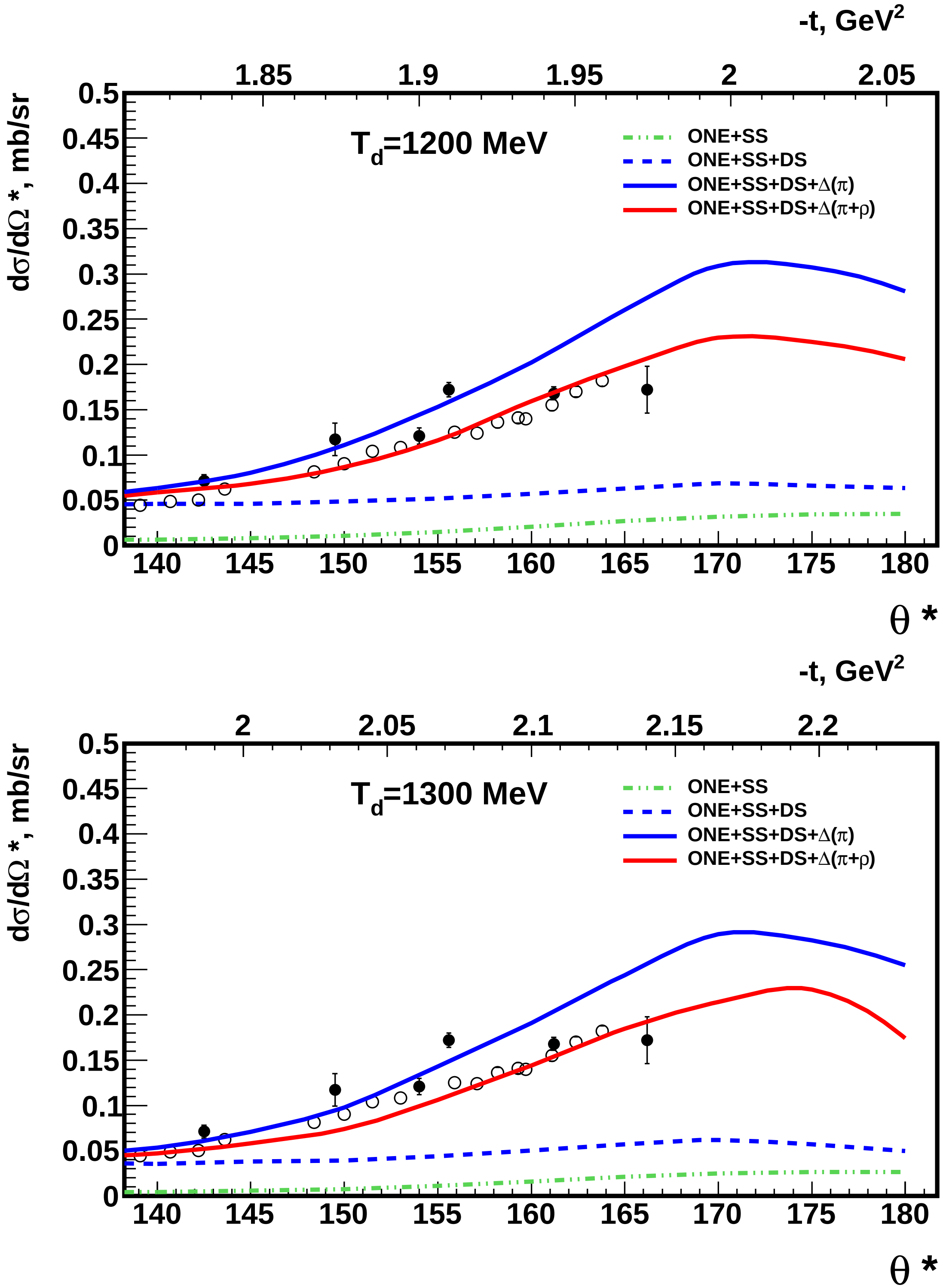
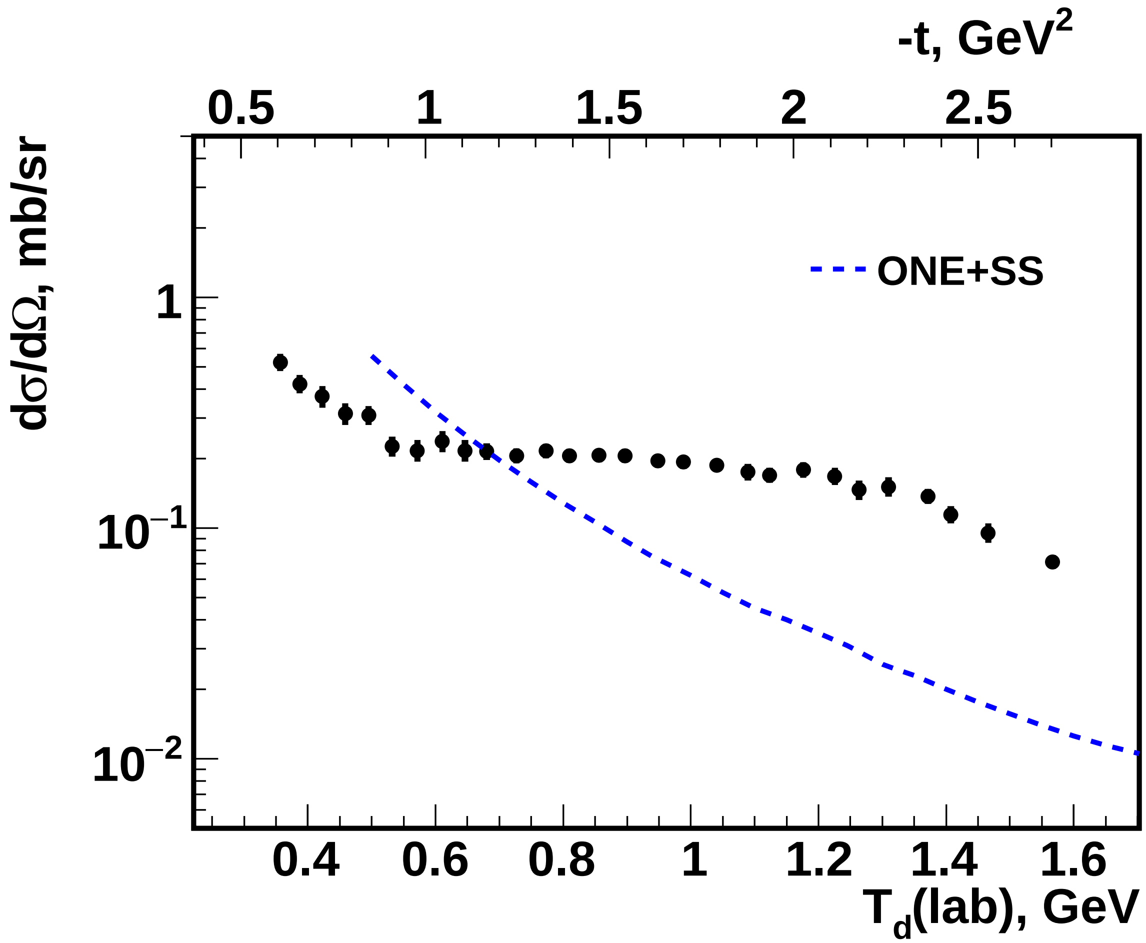


● - E.T.Boschitz et al.,Phys.Rev.C6, p.457 (1972)

○ - J.C.Alder et al.,Phys.Rev.C6, p.2010 (1972)

Energy dependence of the differential cross section at $\theta^* = 180^0$



• - B.E.Bonner et al.,Phys.Rev.Lett.39, p.1253 (1977)

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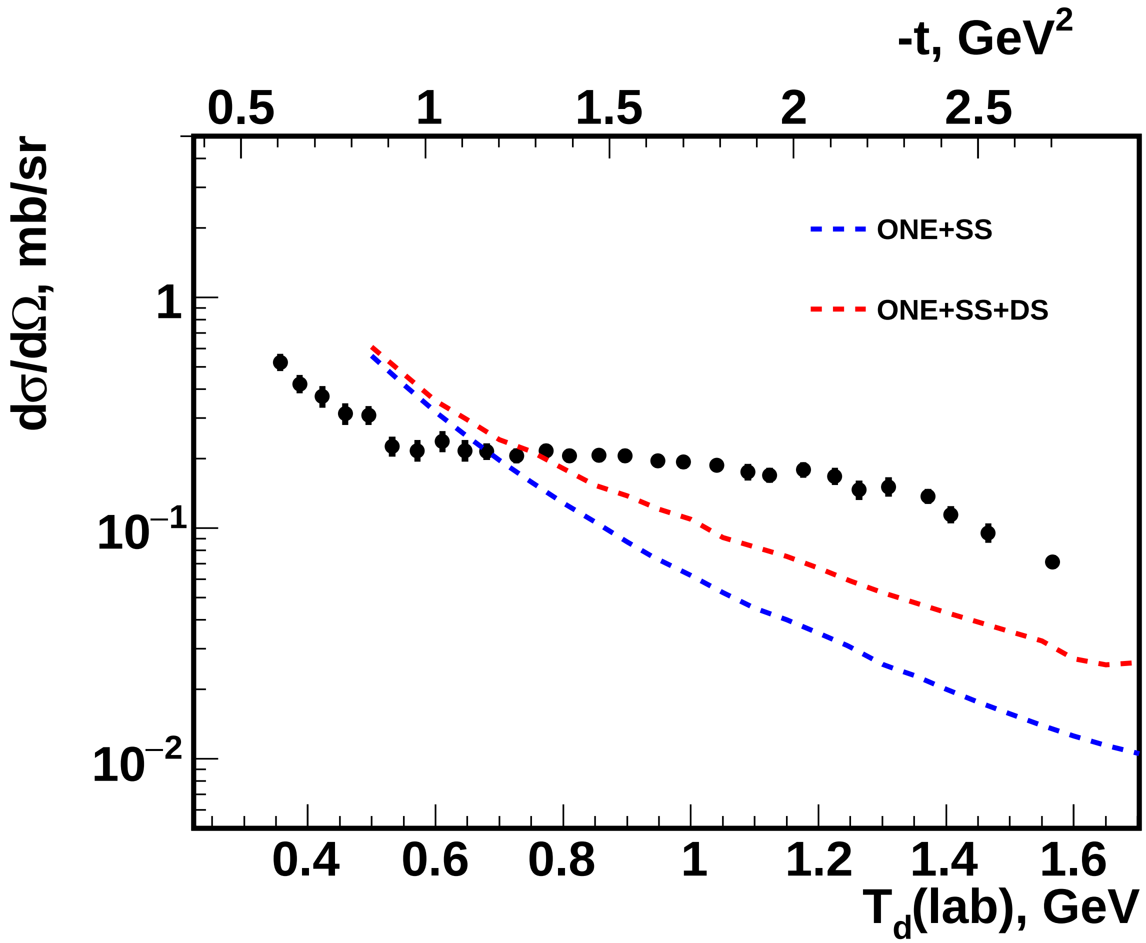

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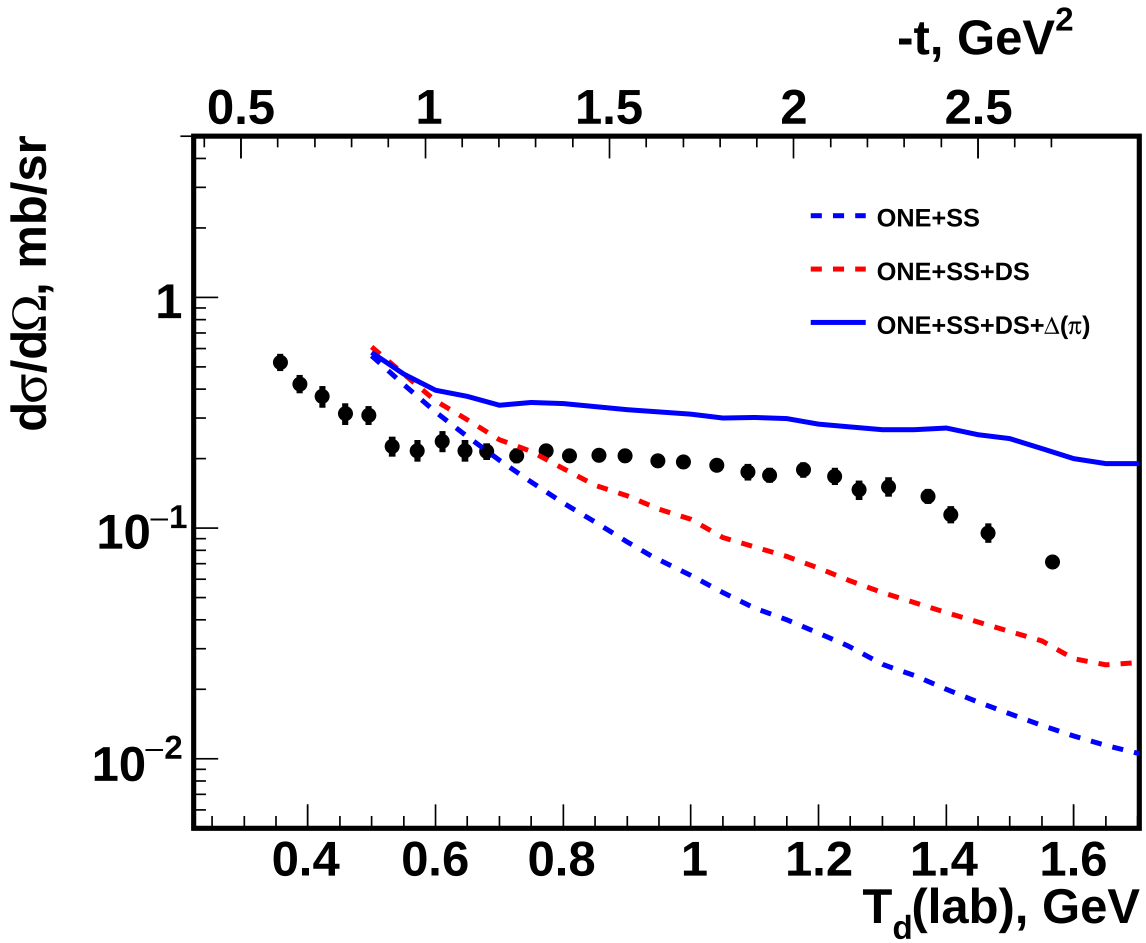

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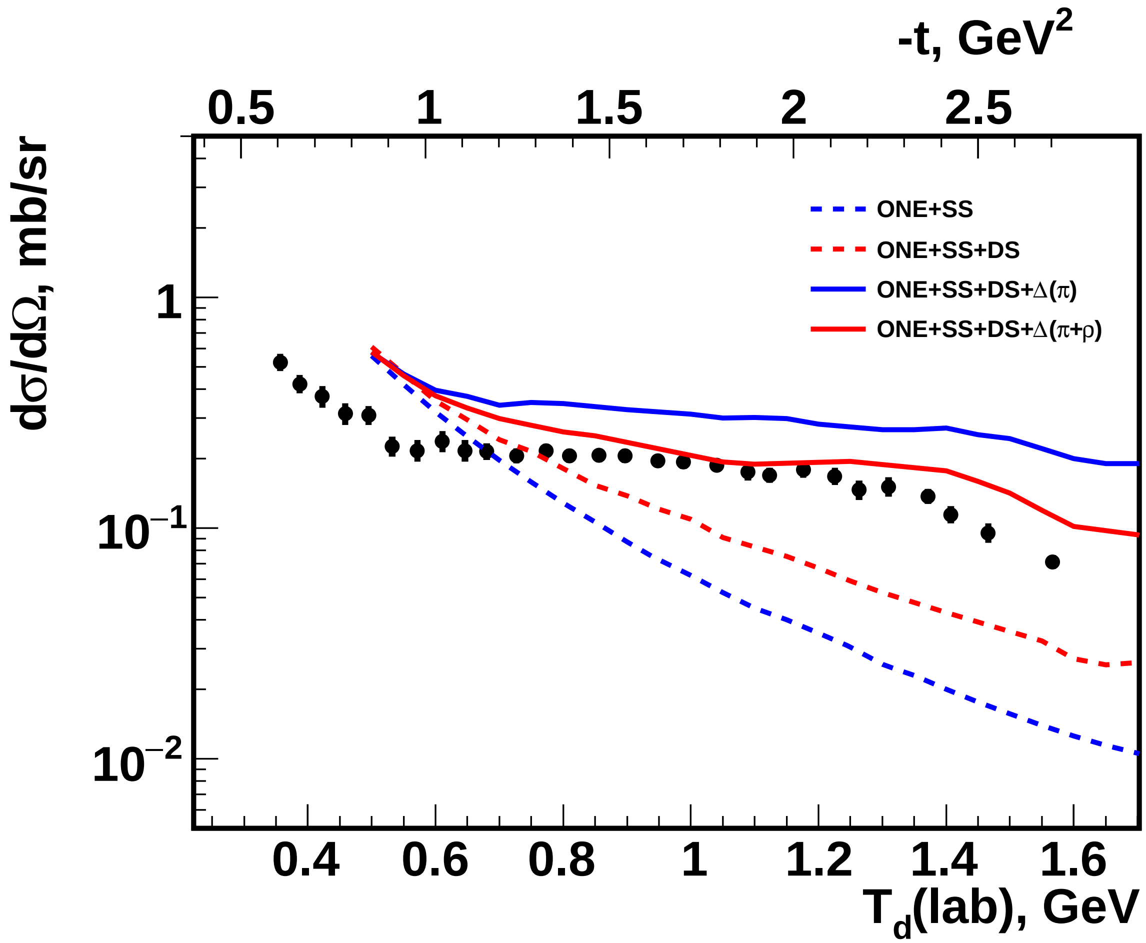

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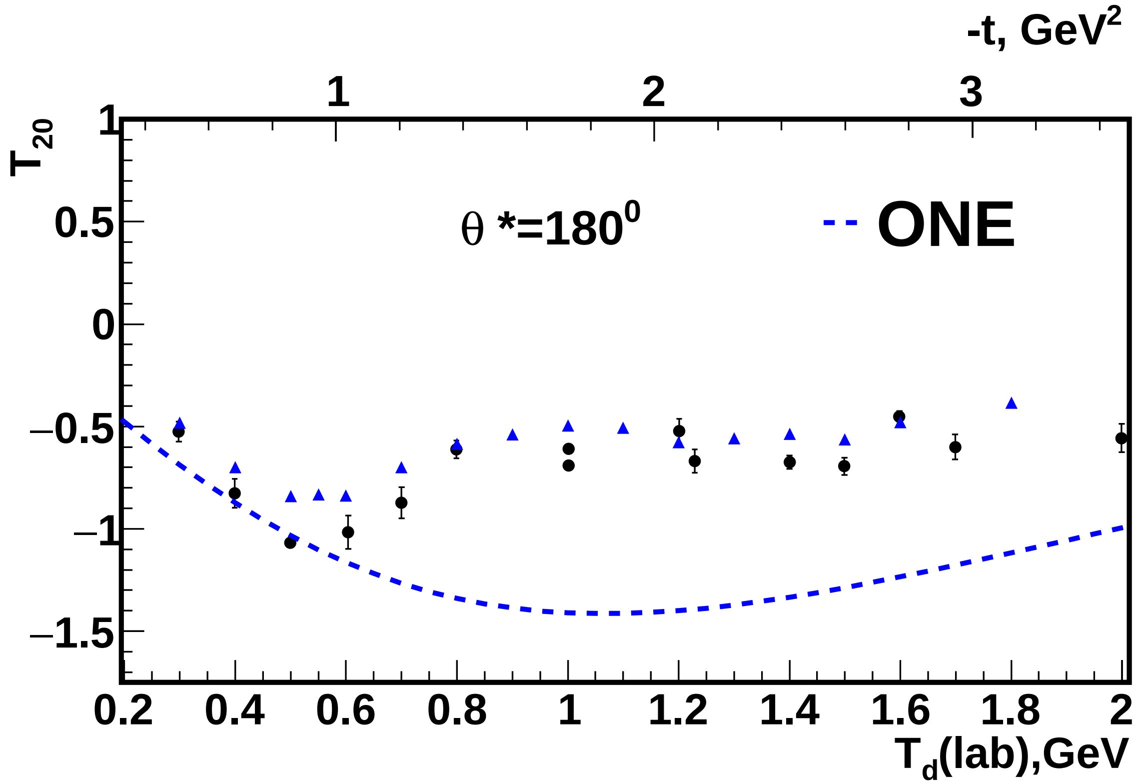

● - J.Arvieux et al.,Nucl.Phys.A431, p.613 (1984)
▲ - V.Punjabi et al.,Phys.Let.B350, p.178 (1995)

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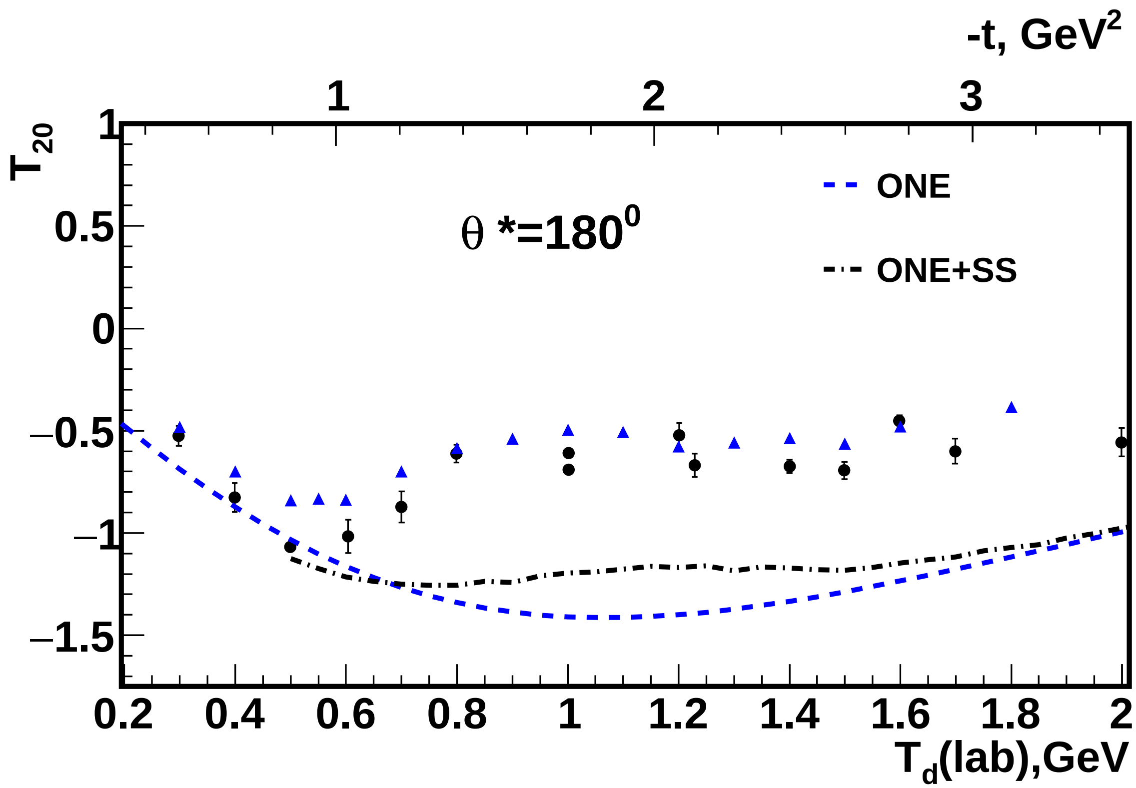

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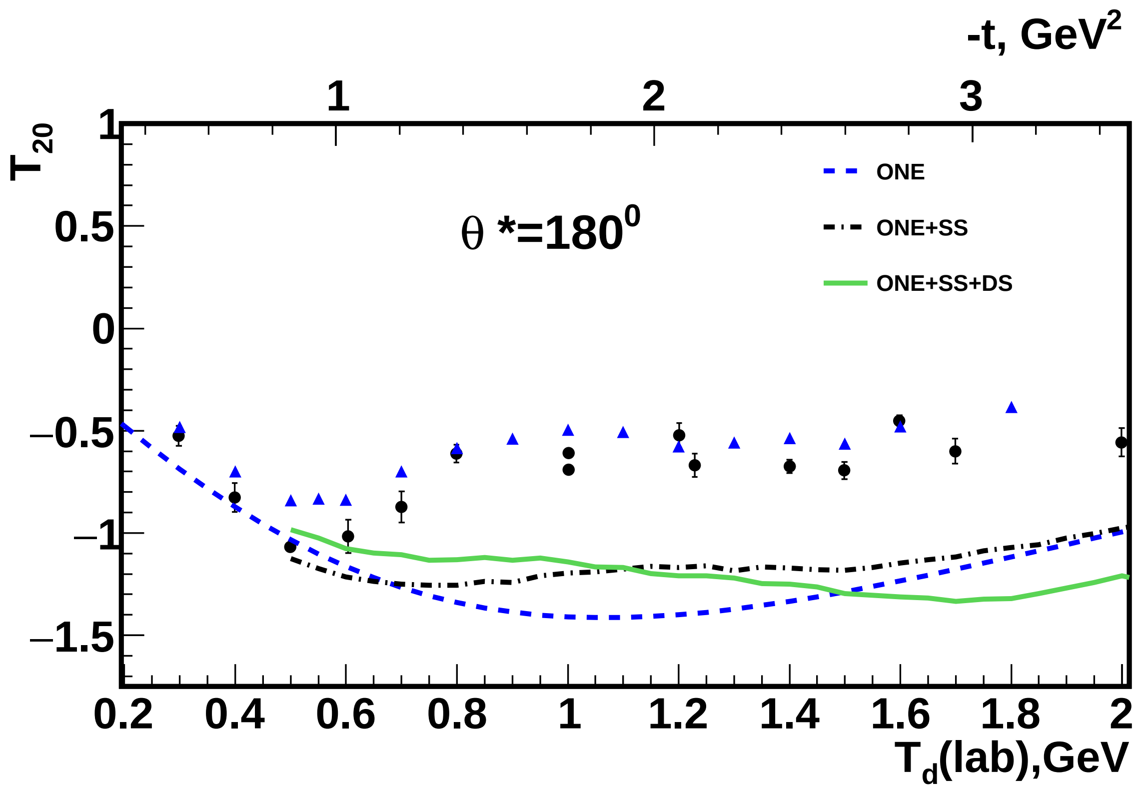

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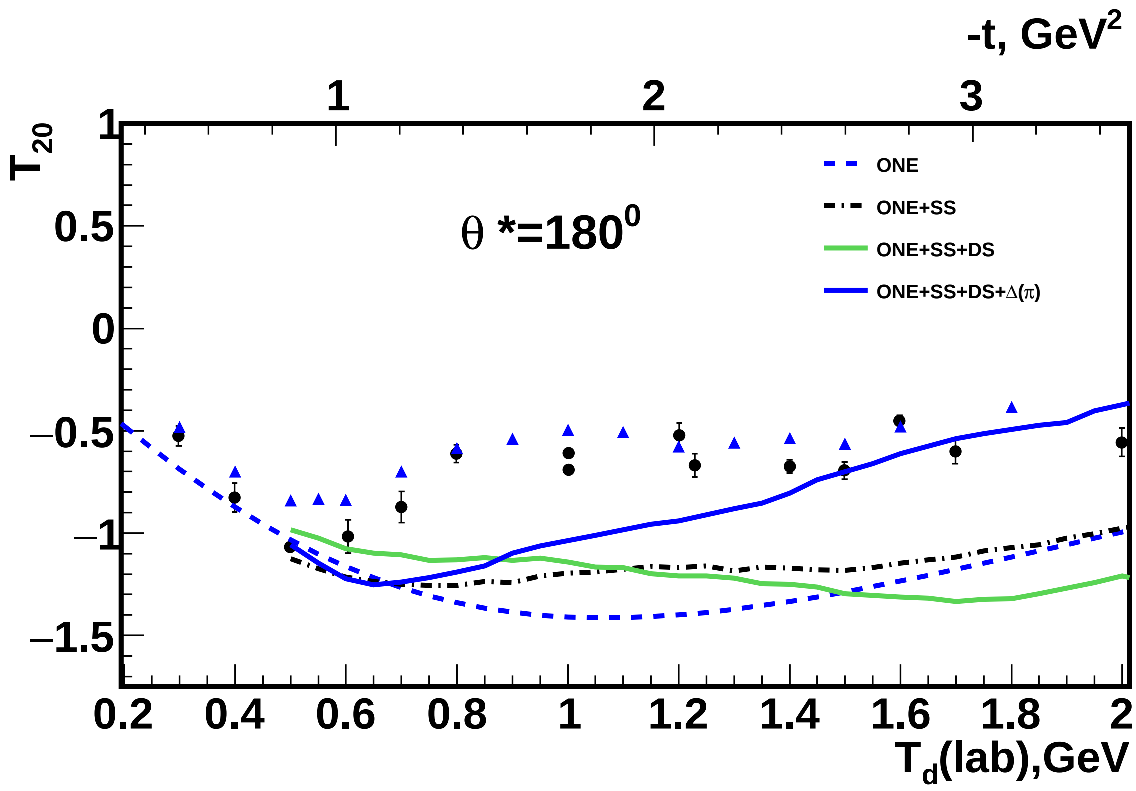

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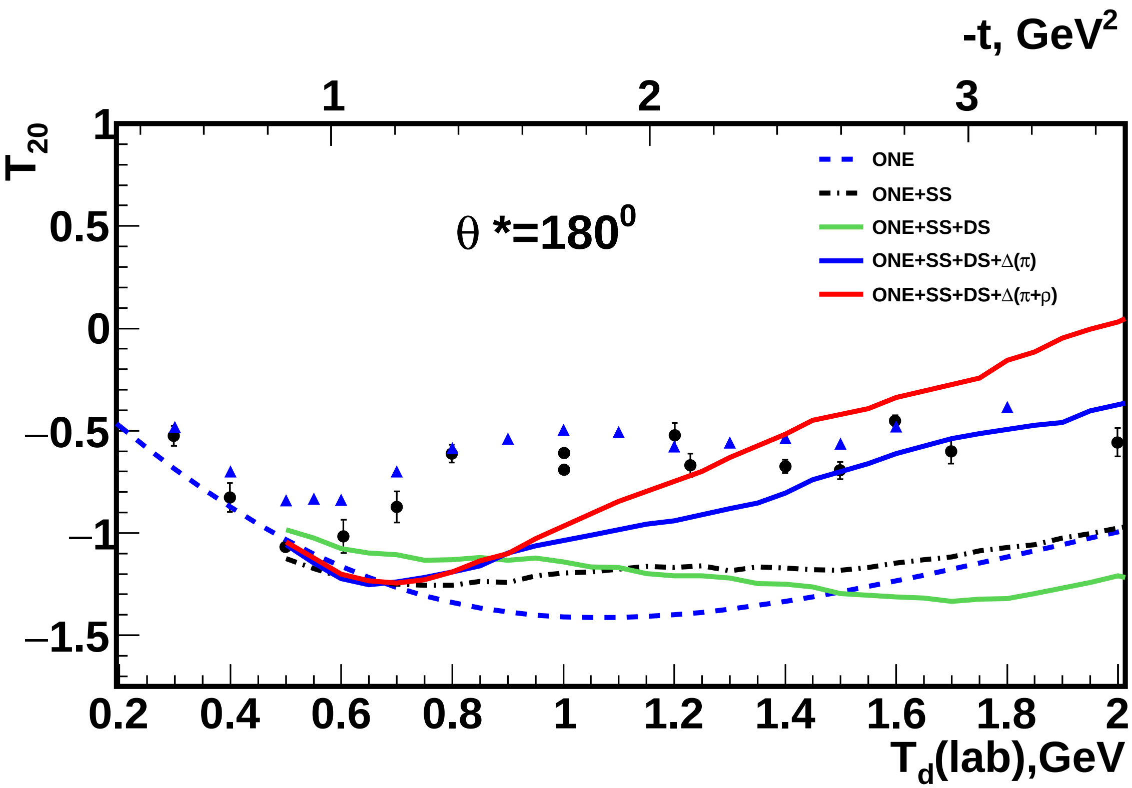

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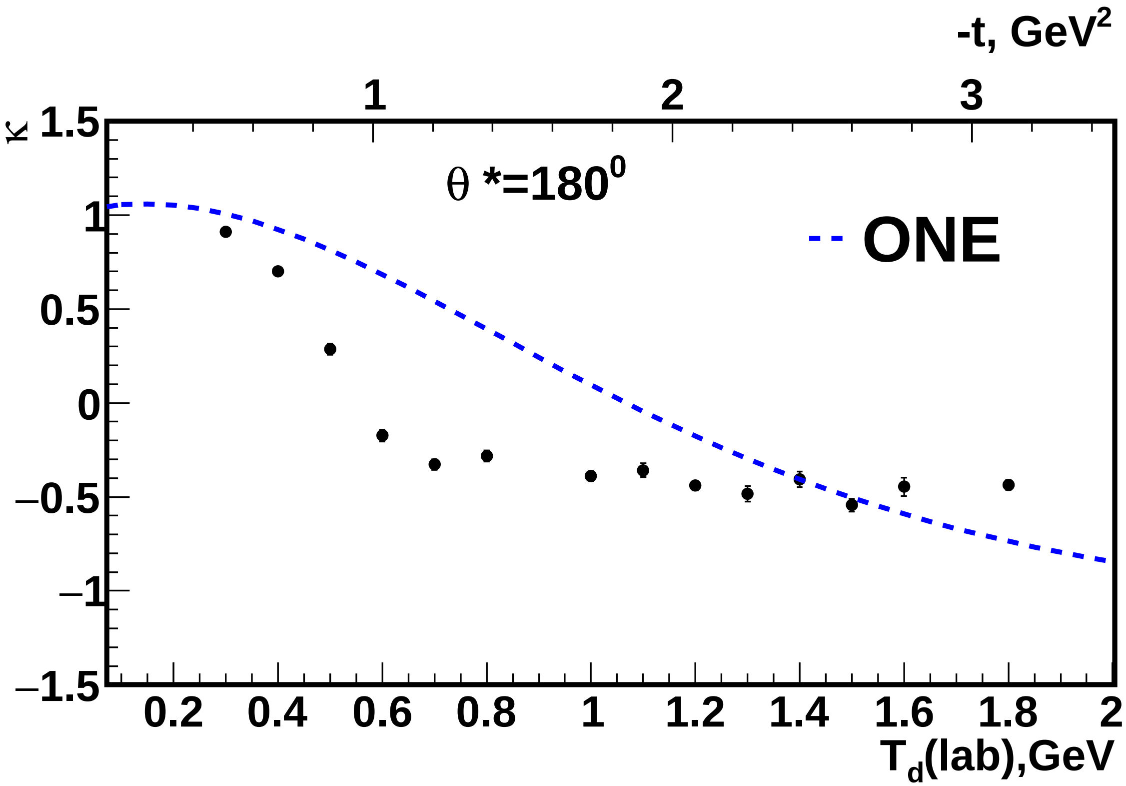
Polarisation transfer in $\vec{d}p \longrightarrow d\vec{p}$ at $\theta^* = 180^0$



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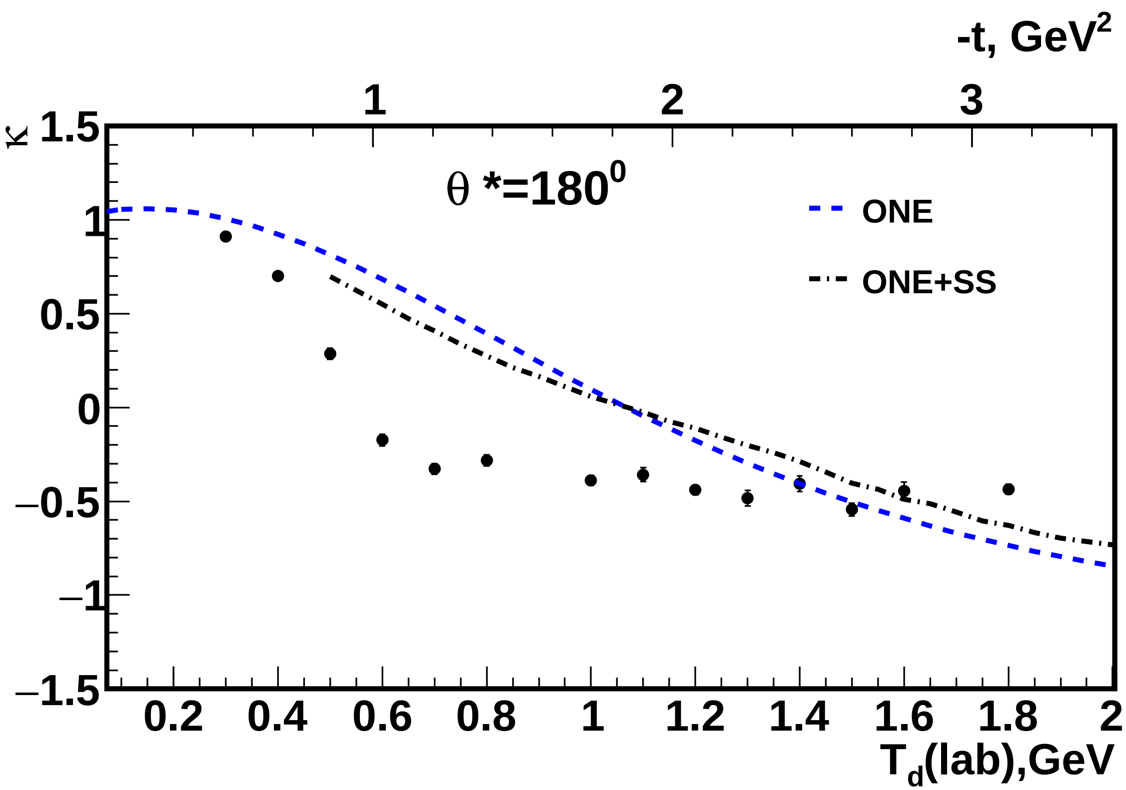
Polarisation transfer in $\vec{d}p \to d\vec{p}$ at $\theta^* = 180^0$



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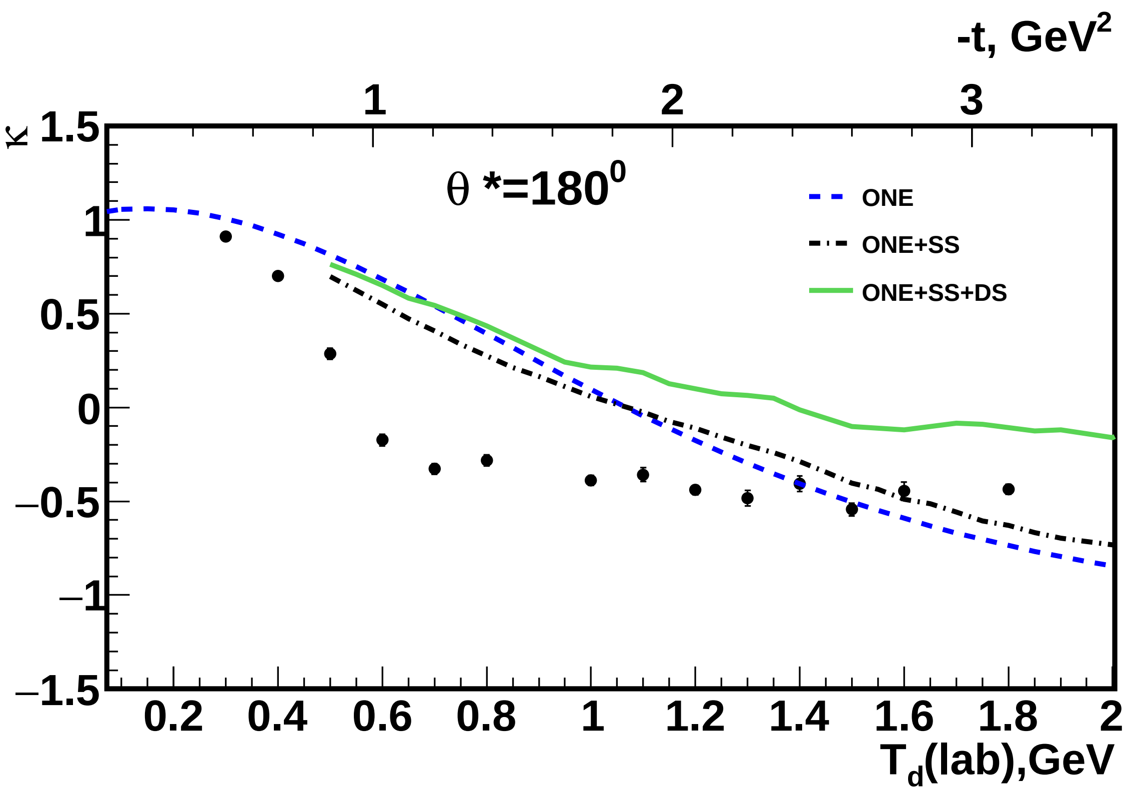

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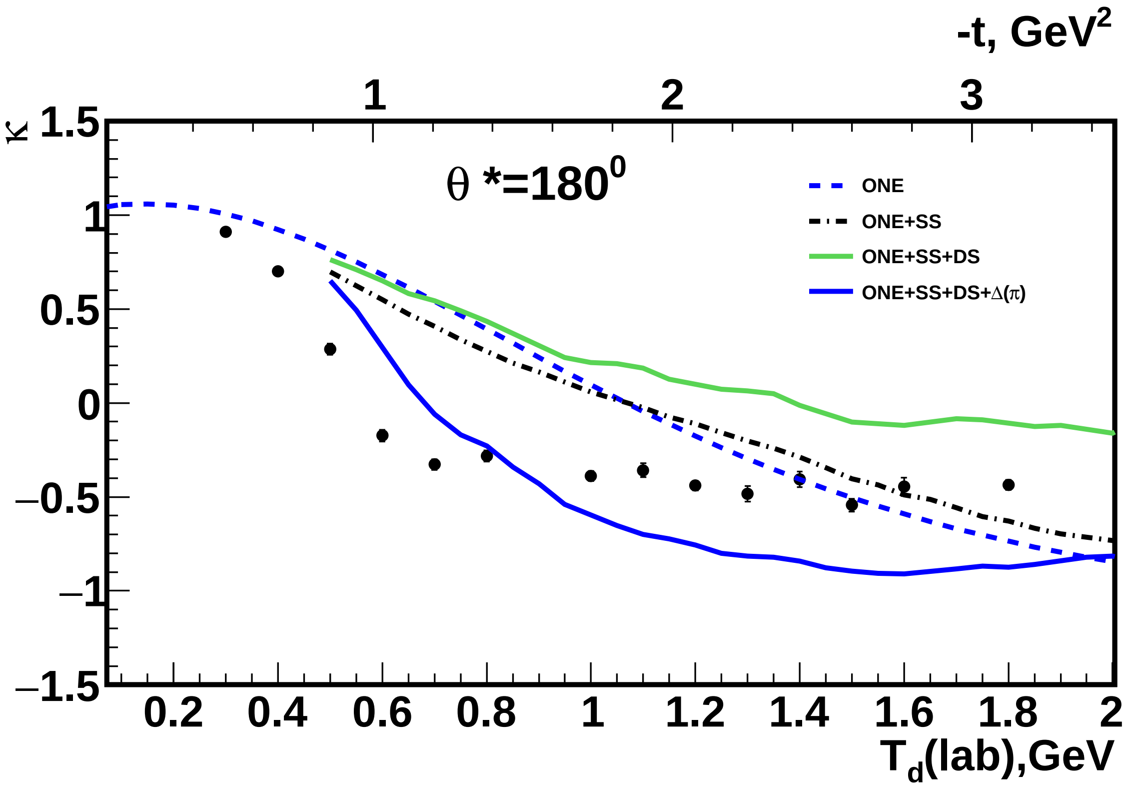

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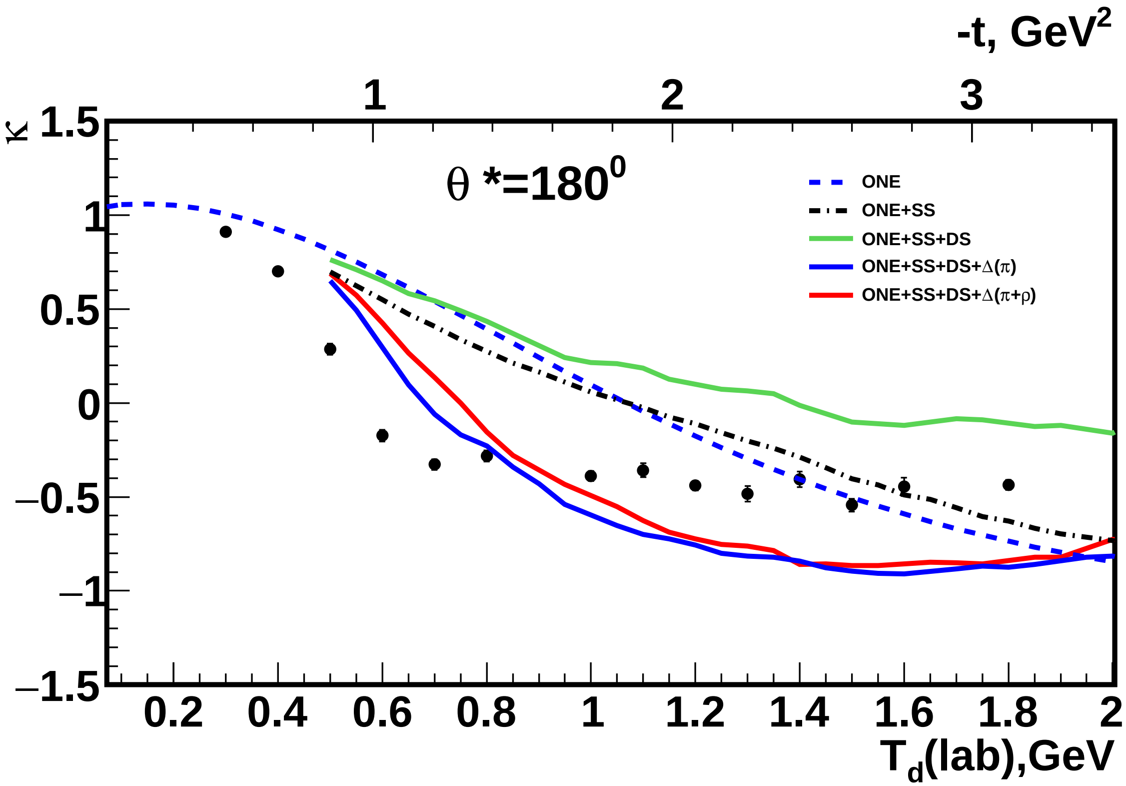
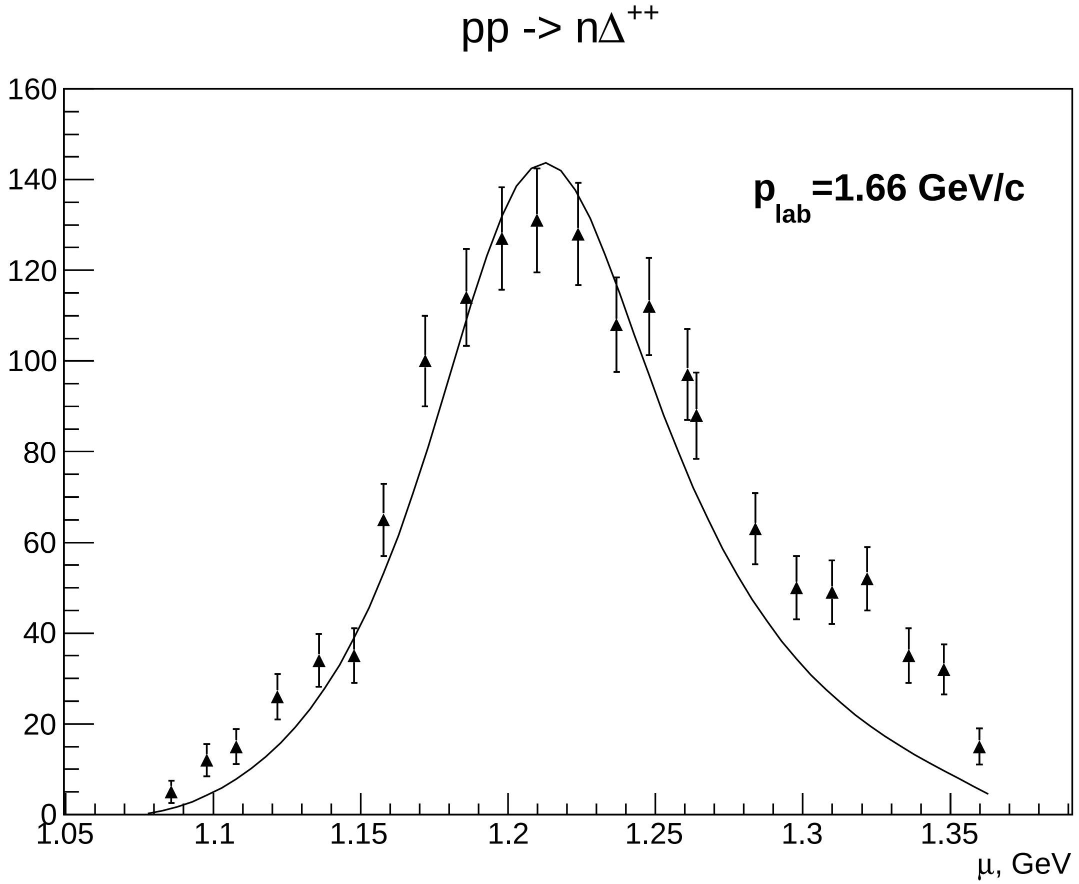


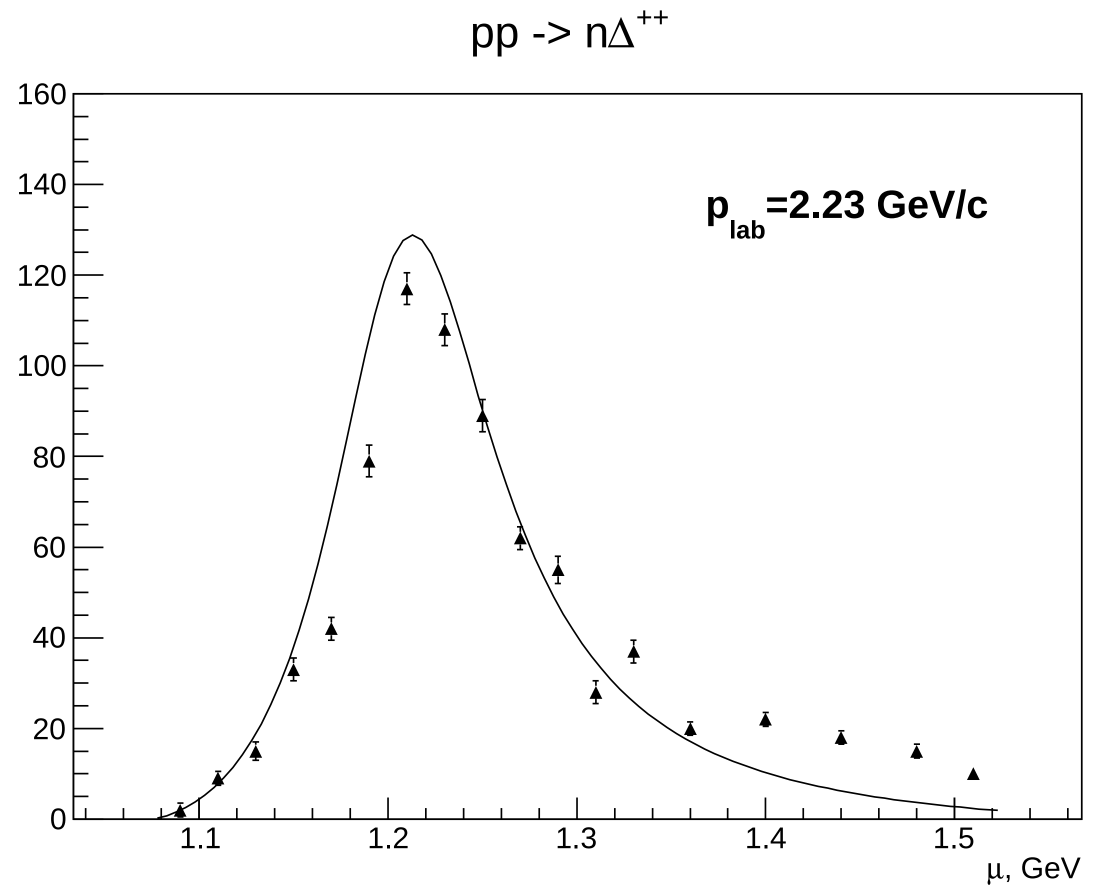
- ● - V.Punjabi et al.,Phys.Let.B350, p.178 (1995)

Conclusion

- **dp backward elastic scattering has been considered taking into account four contributions: one-nucleon-exchange, single-scattering, double-scattering, and Δ-excitation in an intermediate state.**
- **Inclusion of the Δ-isobar term into consideration allows to describe the rise of the differential cross section at $\theta^* \geq 140^\circ$ in the energy range between 880 and 1300 MeV.**
- **The reaction mechanisms have been also studied at the scattering angle $\theta^* = 180^\circ$. It has been obtained a quite good agreement between the experimental data and the theoretical predictions for the energy dependence of the differential cross section.**
- **Some progress has been achieved in the description of the tensor analyzing power T_{20} and polarisation transfer κ.**



▲ - from V.Dmitriev, O.Sushkov and C. Gaarde, Nucl.Phys. A459 (1986) 503



▲ - from V.Dmitriev, O.Sushkov and C. Gaarde, Nucl.Phys. A459 (1986) 503