Proton-Deuteron Scattering and Test of Time-Reversal Invariance

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- Motivation:
  P-even **T**ime-**R**eversal **I**nvariance test planned at **C**OSY (TRIC) (Forschungszentrum Jülich, Germany)
- Null-test for T-odd P-even effects in pd interaction
- Capability of the Glauber model at ∼100-200 MeV
- Coulomb effects
- Total polarized pd cross sections
- Sorces for some false effects
- Differential observables A_y,P_y, $K_z^{x'}$, $K_x^{z'}$ and T-odd effects

Yu.N. Uzikov, J. Haidenbauer, PRC ***87*** *(2013) 054003; PRC* ***88*** *(2013) 027001;*
*A.A. Temerbayev, Yu.N.Uzikov, Phys.At.Nucl.****78*** *(2015) 38;*
arXive:1506.08303(nucl-th), (to appear in PRC)

Why search for Time-invariance Violation?

Baryon Asymmetry of the Universe (BAU) → today:

$$\eta = \left(\frac{n_B - n_{\bar{B}}}{n_\gamma}\right) \approx \left(\frac{n_B}{n_\gamma}\right) \approx 6 \times 10^{-10}$$

(WMAP + COBE, 2003; Steigman 2012)

SM: Estimates of baryon excess much too small, $n_B / n_\gamma \approx 5 \times 10^{-19}$

☛ $(n_B - n_{\bar{B}})$ larger than expected → new sources of $\not{C}\not{P}$ needed

Sakharov: Three Requirements:

- Baryon number violation
- Violation of C and CP symmetries
- Departure from thermodynamic equilibrium

A. Sakharov; JETP Lett, 5, 24

From talk by W.Karsch, PANIC-2014

- CP-violation in K- and B-meson physics $\Longrightarrow$ T-violation
- The T- violating, P-violating (TVPV) effects arise in SM through CP violating phase of CKM matrix (and through the QCD $\theta-$ term)
- T-violating P-conserving (TVPC) (flavor-conserving) effects do not arise in SM as Fundamental interactions,

  but could be generated through weak corrections to T-odd P-odd interactions

  ⋆ I.B. Khriplovich Nucl.Phys. B **352** (1991) 385: relative strength of the T-odd, P-even nuclear force does not exceed $\alpha_T \sim 2\times 10^{-6}$

  ⋆ CP violation in SM leads to simultaneous violation of CP and P-invariance. Therefore, to produce CP-odd P-even term one should have one additional P-odd term in the effective interaction: $\mathbf{g} \sim \mathbf{M^4 G_F^2} \sin\delta \sim \mathbf{10^{-10}}$

  V.P. Gudkov, Phys. Rep. **212**(1992)77

  ⋆ …much larger g is not excluded as the low energy limit of some unknown interaction beyond the SM

TVPC ($\equiv$ T-odd P-even) interactions in terms of boson exchanges :
M.Simonius, Phys. Lett. **58B** *(1975) 147; PRL* **78** *(1997) 4161*

- $\star$ $J \geq 1$
- $\star$ π, σ-exchanges do not contribute
- $\star$ The lowest mass meson allowed is the ρ-meson $/I^G(J^{PC}) = 0^+(1^{--})/$
- $\star$ Natural parity exchange $(P = (-1)^J)$ must be charged

The TVPC Born NN-amplitude

$$\widetilde{V}_\rho^{TVPC} = \bar{g}_\rho \frac{g_\rho \kappa}{2M} [\vec{\tau}_1 \times \vec{\tau}_2]_z \frac{1}{m_\rho^2 + |\vec{q}|^2} \times i[(\vec{p}_f + \vec{p}_i) \times \vec{q}] \cdot (\vec{\sigma}_1 - \vec{\sigma}_2) \quad (1)$$

C-odd (hence T-odd), only charged ρ's. No contribution to the nn or pp.

$\vec{q} = \vec{p}_f - \vec{p}_i$ dissappeares at $\vec{q} = 0$

Axial $a_1(1170)$-meson exchange $I^G(J^{PC}) = 0^-(1^{+-})$ ...

The most general structure contains 18 terms *P. Herczeg, Nucl.Phys.* **75** *(1966) 655*

Experimental constraints (direct and indirect)

- Test of the detailed balance $^{27}Al(p,\alpha)^{24}Mg$ and $^{24}Mg(\alpha,p)^{27}Al$, $\Delta=(\sigma_{dir}-\sigma_{inv})/(\sigma_{dir}+\sigma_{inv})\leq 5.1\times 10^{-3}$ (E.Blanke et al. PRL **51** (1983) 355) is not simply related to the NN T-odd P-even interaction
Numerous statistical analyses including nuclear energy-level fluctuations (J.B. French et al. PRL **54** (1985) 2313) $\alpha_T < 2\times 10^{-3}$
- $\vec{n}$ transmission through ^{165}Ho (P.R. Huffman et al. PRC **55** (1997) 2684)

$$\alpha_T \leq 7.1\times 10^{-4} \quad (\text{or } \bar{g}_\rho \leq 5.9\times 10^{-2})$$

- Elastic $\vec{p}n$ and $\vec{n}p$ scattering, A^p, P^p, A^n, P^n; CSB $(A = A^n - A^p)$ (M. Simonius, PRL **78** (1997) 4161)

$$\alpha_T \leq 8\times 10^{-5} \ (\text{ or } \bar{g}_\rho < 6.7\times 10^{-3})$$

- indirect from T-odd P-odd (EDM) $\alpha_T \leq 1.1\times 10^{-5}$ (or $\bar{g}_\rho \leq \times 10^{-3}$) (W.C. Haxton, A. Höring, M.J. Musolf, PRD **50** (1994) 3422)
But Kurylov A., McLaughlin G.C., Ramsey-Musolf M., PRD 63(2001)076007: **no constraints within the "B"-scenario**

- TRIC (D. Eversheim, B. Lorentz, Yu. Valdau. COSY proposal N 215): $\vec{p}(p_y^p) + d(P_{xz})$ transmission in the COSY ring

  The goal is to improve the direct upper bound on TVPC by one order of magnitude.

  Theory:
  M. Beyer, Nucl.Phys. A 560 (1993) 895;
  d-breakup channel only, 135 MeV;
  Y.-Ho Song, R. Lazauskas, V.Gudkov, PRC
  84 (2011) 025501; Faddeev eqs., nd-scattering,100 keV;
  A.A. Temerbayev, Yu.N. Uzikov, Yad. Fiz. **78** (2015) 38; (Glauber theory)
  Yu.N. Uzikov, A.A. Temerbayev, nucl-theor:1504.06601 (SPIN2014, Beijing, 20-24 October, 2014); to appear in Phys.Rev. C

$$\frac{1}{2} + 1 \to \frac{1}{2} + 1$$

$(2+1)^2(2\frac{1}{2}+1)^2 = 36$ transition amplitudes

P-parity $\Longrightarrow$ 18 independent amplitudes

T-invariance $\Longrightarrow$ 12 independent amplitudes

At $\theta_{cm} = 0 \Longrightarrow$ 4 (for T-inv. P-inv.) $+$ 1 (T- viol. P-inv.)

Transition matrix element

$$< p'\mu', d'\lambda'|M|p\mu, d\lambda >= \varphi^{+}_{\mu'} e^{(\lambda')^{*}}_{\beta} M_{\beta\alpha}(\mathbf{p}, \mathbf{p}', \boldsymbol{\sigma}) e^{(\lambda)}_{\alpha} \varphi_{\mu},$$

$\alpha, \beta = x, y, z$

$\mathbf{r} \to -\mathbf{r}$ P-invariance:

$$M_{\beta\alpha}(-\mathbf{p}, -\mathbf{p}', \boldsymbol{\sigma}) = M_{\beta\alpha}(\mathbf{p}, \mathbf{p}', \boldsymbol{\sigma}),$$

T-invariance:

$$M_{\beta\alpha}(\mathbf{p}, \mathbf{p}', \boldsymbol{\sigma}) = M_{\alpha\beta}(-\mathbf{p}', -\mathbf{p}, -\boldsymbol{\sigma}).$$

Phenomenology of the $pd \to pd$ transition

$\hat{\mathbf{q}} = (\mathbf{p} - \mathbf{p}')$, $\hat{\mathbf{k}} = (\mathbf{p} + \mathbf{p}')/$, $\hat{\mathbf{n}} = [\mathbf{k} \times \mathbf{q}]$ – unit vect. ($Z \uparrow\uparrow \hat{\mathbf{k}}$, $X \uparrow\uparrow \hat{\mathbf{q}}$ $Y \uparrow\uparrow \hat{\mathbf{n}}$)

$$M = (A_1 + A_2\boldsymbol{\sigma}\hat{\mathbf{n}}) + (A_3 + A_4\boldsymbol{\sigma}\hat{\mathbf{n}})(\mathbf{S}\hat{\mathbf{q}})^2 + (A_5 + A_6\boldsymbol{\sigma}\hat{\mathbf{n}})(\mathbf{S}\hat{\mathbf{n}})^2 + A_7(\boldsymbol{\sigma}\hat{\mathbf{k}})(\mathbf{S}\hat{\mathbf{k}}) + A_8(\boldsymbol{\sigma}\hat{\mathbf{q}})\left[(\mathbf{S}\hat{\mathbf{q}})(\mathbf{S}\hat{\mathbf{n}}) + (\mathbf{S}\hat{\mathbf{n}})(\mathbf{S}\hat{\mathbf{q}})\right] + (A_9 + A_{10}\boldsymbol{\sigma}\hat{\mathbf{n}})(\mathbf{S}\hat{\mathbf{n}}) + A_{11}(\boldsymbol{\sigma}\hat{\mathbf{q}})(\mathbf{S}\hat{\mathbf{q}}) + A_{12}(\boldsymbol{\sigma}\hat{\mathbf{k}})\left[(\mathbf{S}\hat{\mathbf{k}})(\mathbf{S}\hat{\mathbf{n}}) + (\mathbf{S}\hat{\mathbf{n}})(\mathbf{S}\hat{\mathbf{k}})\right]$$

− −

$$+(T_{13} + T_{14}\boldsymbol{\sigma}\hat{\mathbf{n}})\left[(\mathbf{S}\hat{\mathbf{k}})(\mathbf{S}\hat{\mathbf{q}}) + (\mathbf{S}\hat{\mathbf{q}})(\mathbf{S}\hat{\mathbf{k}})\right] + T_{15}(\boldsymbol{\sigma}\hat{\mathbf{q}})(\mathbf{S}\hat{\mathbf{k}}) + T_{16}(\boldsymbol{\sigma}\hat{\mathbf{k}})(\mathbf{S}\hat{\mathbf{q}}) + T_{17}(\boldsymbol{\sigma}\hat{\mathbf{k}})\left[(\mathbf{S}\hat{\mathbf{q}})(\mathbf{S}\hat{\mathbf{n}}) + (\mathbf{S}\hat{\mathbf{n}})(\mathbf{S}\hat{\mathbf{q}})\right] + T_{18}(\boldsymbol{\sigma}\hat{\mathbf{q}})\left[(\mathbf{S}\hat{\mathbf{k}})(\mathbf{S}\hat{\mathbf{n}}) + (\mathbf{S}\hat{\mathbf{n}})(\mathbf{S}\hat{\mathbf{k}})\right]$$

T-even P-even: $A_1 \div A_{12}$
(see M. Platonova, V.I. Kukulin,PRC **81** (2010) 014004)

<u>$\mathbf{T_{13} \div T_{18}}$: **TVPC**</u>

The polarized elastic differential pd cross section

$$\left(\frac{d\sigma}{d\Omega}\right)_{pol} = \left(\frac{d\sigma}{d\Omega}\right)_0 \left[1 + \frac{3}{2}p_j^p p_i^d C_{j,i} + \frac{1}{3}P_{ij}^d A_{ij} + \ldots\right]. \quad (2)$$

$$C_{y,y} = TrMS_y\sigma_y M^+/TrMM^+, \quad \ldots \quad (3)$$

Forward elastic pd scattering amplitude (P-even, T-even):

$$e'^{*}_{\beta}\hat{M}_{\alpha\beta}(0)e_{\alpha} = g_1[\mathbf{e}\,\mathbf{e}'^{*} - (\hat{\mathbf{k}}\mathbf{e})(\hat{\mathbf{k}}\mathbf{e}'^{*})] + g_2(\hat{\mathbf{k}}\mathbf{e})(\hat{\mathbf{k}}\mathbf{e}'^{*}) +$$
$$ig_3\{\boldsymbol{\sigma}[\mathbf{e}\times\mathbf{e}'^{*}] - (\boldsymbol{\sigma}\hat{\mathbf{k}})(\hat{\mathbf{k}}\cdot[\mathbf{e}\times\mathbf{e}'^{*}])\} + ig_4(\boldsymbol{\sigma}\hat{\mathbf{k}})(\hat{\mathbf{k}}\cdot[\mathbf{e}\times\mathbf{e}'^{*}]) + \quad (4)$$

M.P. Rekalo et al., Few-Body Syst. 23, 187 (1998)

. . . and plus **T-odd P-even (TVPC) term**

$$\cdots + \widetilde{\mathbf{g}}_5\{(\boldsymbol{\sigma}\cdot[\hat{\mathbf{k}}\times\mathbf{e}])(\mathbf{k}\cdot\mathbf{e}'^{*}) + (\boldsymbol{\sigma}\cdot[\hat{\mathbf{k}}\times\mathbf{e}'^{*}])(\mathbf{k}\cdot\mathbf{e})\}; \quad (5)$$

Non-diagonal:

$$< \mu' = \frac{1}{2}, \lambda' = 0|M^{TVPC}|\mu = -\frac{1}{2}, \lambda = 1 >= i\sqrt{2}\widetilde{\mathbf{g}}_5. \quad (6)$$

Generalized Optical theorem:

$$Im\frac{Tr(\hat{\rho}_i\hat{M}(0))}{Tr\hat{\rho}_i} = \frac{k}{4\pi}\sigma_i \quad (7)$$

Total polarized cross sections pd

$$\sigma_{tot} = \underbrace{\sigma_0 + \sigma_1 \mathbf{p}^p \cdot \mathbf{P}^d + \sigma_2 (\mathbf{p}^p \cdot \hat{\mathbf{k}})(\mathbf{P}^d \cdot \hat{\mathbf{k}}) + \sigma_3 P_{zz}}_{T-even, P-even} + \underbrace{\widetilde{\sigma}_{tvpc} p_y^p P_{xz}^d}_{T-odd, P-even}$$

with

$$\sigma_0 = \frac{4\pi}{k} Im \frac{2g_1 + g_2}{3}, \sigma_1 = -\frac{4\pi}{k} Im g_3,$$
$$\sigma_2 = -\frac{4\pi}{k} Im(g_4 - g_3), \sigma_3 = \frac{4\pi}{k} Im \frac{g_1 - g_2}{6}.$$

/Yu.N. Uzikov, J. Haidenbauer, PRC ***79*** *(2009) 024617; PRC* ***87*** *(2013) 054003/*

$$\widetilde{\sigma}_{tvpc} = -\frac{4\pi}{k} Im \frac{2}{3} \widetilde{\mathbf{g}}_5 \tag{8}$$

/Yu.N. Uzikov,A.A. Temerbayev to appear in Phys. Rev. C/

Measurement of total $\widetilde{\sigma}_{tvpc}$ in $\vec{p}-\vec{d}$ scattering:

- a true null-test for T-invariance
- independent on dynamics
- FSI $\&$ ISI is yet included into "exact" $F(0)$

Comments to "Nonexistence proof":

"It is impossible to construct, in any reaction in atomic, nuclear, or particle physics, a null experiment that would unambiguously test the time-reversal invariance independently of dynamical assumptions"

F.Arash, M.J. Moravcsik, G.R. Goldstein, Phys.Rev.Lett. **54** *(1985) 2649*

Proof holds for bilinear ($\sim |F_{if}|^2$) observables only

H.E. Conzett, Phys. Rev. C **48** *(1993) 423*

Transmission experiments are not included into that proof;
V.E. Bunakov, L.B. Pikelner, Prog. Part. Nucl. Phys. **39** *(1997) 377*

Backround conditions for TRIC? Elastic $pd \to pd$ transitions

$$\hat{M}(\mathbf{q},\mathbf{s}) =$$
$$\exp\left(\frac{1}{2}i\mathbf{q}\cdot\mathbf{s}\right)M_{pp}(\mathbf{q}) + \exp\left(-\frac{1}{2}i\mathbf{q}\cdot\mathbf{s}\right)M_{pn}(\mathbf{q}) +$$
$$+\frac{i}{2\pi^{3/2}}\int \exp\left(i\mathbf{q}'\cdot\mathbf{s}\right)\Big[M_{pp}(\mathbf{q}_1)M_{pn}(\mathbf{q}_2) + p \leftrightarrow n\Big]d^2\mathbf{q}'.$$

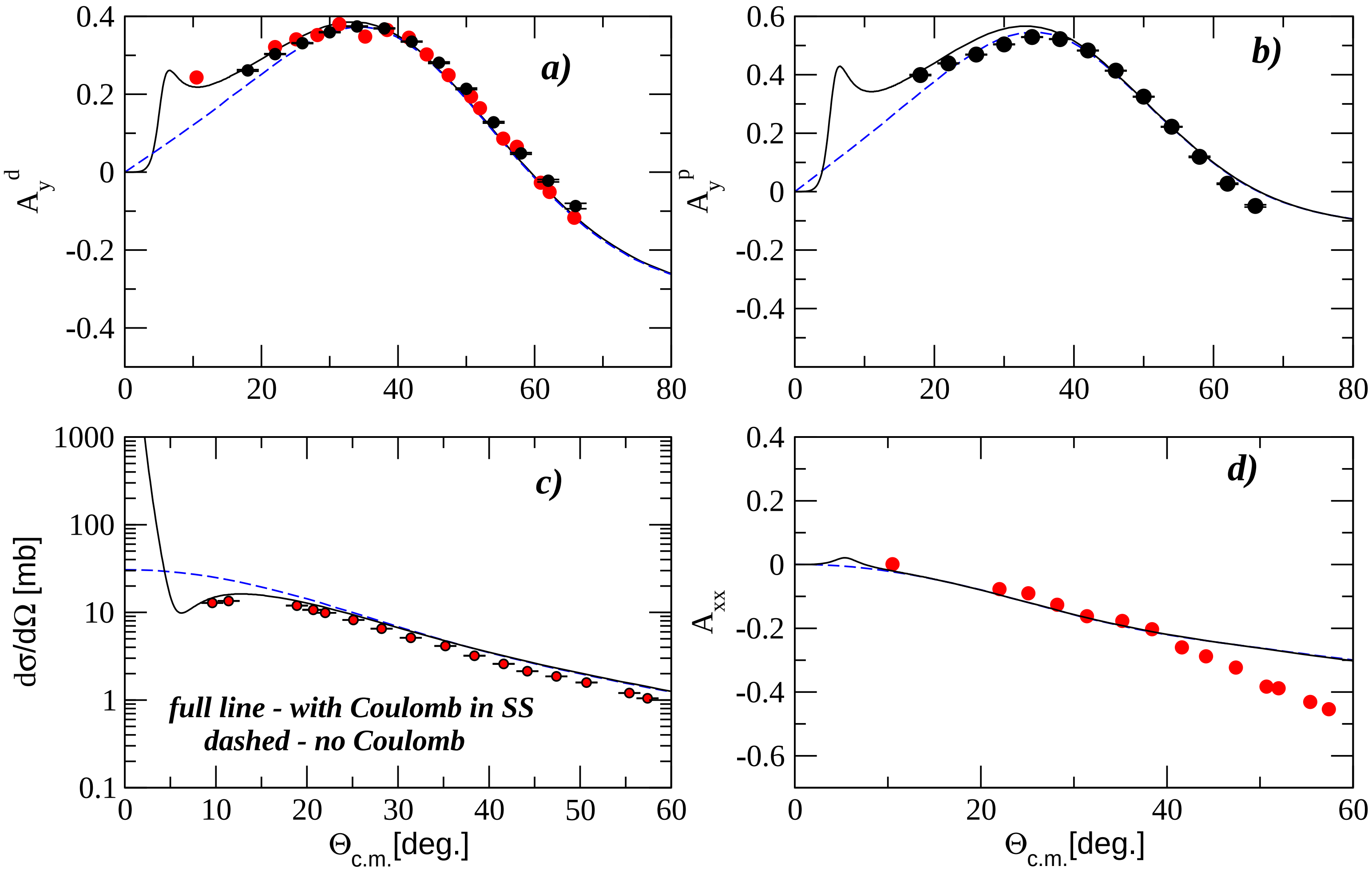
On-shell elastic pN scattering amplitude (**T-even, P-even**)

$$\begin{aligned} M_{pN} &= A_N + (C_N\boldsymbol{\sigma}_1 + C'_N\boldsymbol{\sigma}_2)\cdot\hat{\mathbf{n}} + B_N(\boldsymbol{\sigma}_1\cdot\hat{\mathbf{k}})(\boldsymbol{\sigma}_2\cdot\hat{\mathbf{k}}) + \\ &+ (G_N - H_N)(\boldsymbol{\sigma}_1\cdot\hat{\mathbf{n}})(\boldsymbol{\sigma}_2\cdot\hat{\mathbf{n}}) + (G_N + H_N)(\boldsymbol{\sigma}_1\cdot\hat{\mathbf{q}})(\boldsymbol{\sigma}_2\cdot\hat{\mathbf{q}}) \end{aligned}$$

M. Platonova, V. Kukulin, PRC **81** (2010) 014004:

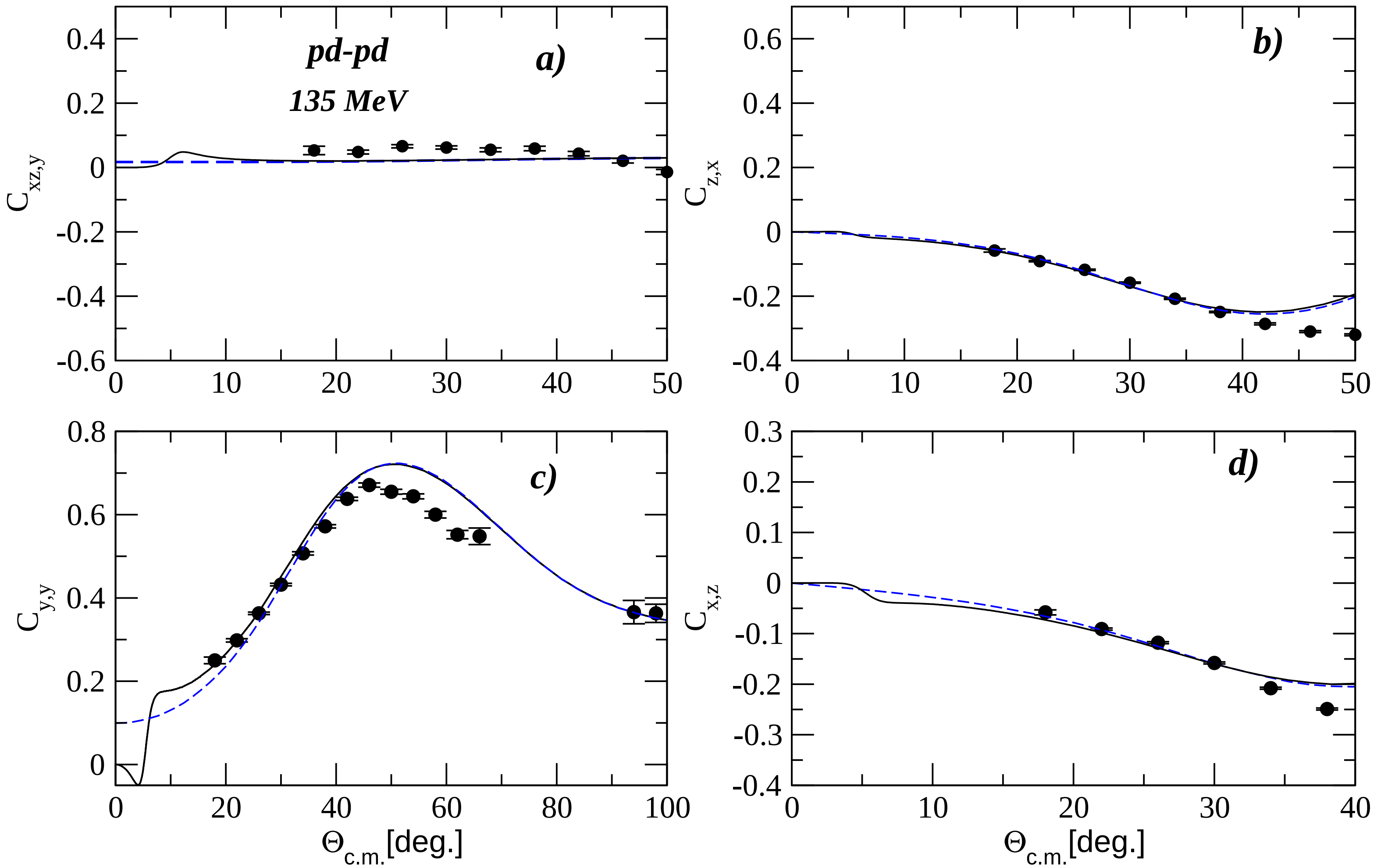
Test calculations: pd elastic scattering at 135 MeV

A.A. Temerbayev, Yu.N.Uzikov, Yad. Fiz. **78** (2015) 38



Data: K. Sekiguchi et al. PRC (2002); B. von Przewoski et al. PRC (2006)
See also Faddeev calculations: A.Deltuva, A.C. Fonseca, P.U. Sauer, PRC 71 (2005) 054005.

Test calculations-II: pd elastic scattering at 135 MeV



Curves: the modified Glauber model; A.A. Temerbayev, Yu.N.Uzikov, Yad. Fiz. **78** (2015) 38
Data: von B.Przewoski et al. PRC 74 (2006) 064003

$$t_{pN} = \underbrace{h_p[(\boldsymbol{\sigma}\cdot\mathbf{p})(\boldsymbol{\sigma}_p\cdot\mathbf{q}) + (\boldsymbol{\sigma}_p\cdot\mathbf{p})(\boldsymbol{\sigma}\cdot\mathbf{q}) - (\boldsymbol{\sigma}_p\cdot\boldsymbol{\sigma})(\mathbf{p}\cdot\mathbf{q})]}_{a1-meson} +$$

$$+g_p[\boldsymbol{\sigma}\times\boldsymbol{\sigma}_p]\cdot[\mathbf{q}\times\mathbf{p}] + \underbrace{g_p'(\boldsymbol{\sigma}-\boldsymbol{\sigma}_p)\cdot i\,[\mathbf{q}\times\mathbf{p}][\boldsymbol{\tau}_1\times\boldsymbol{\tau}_2]_z}_{\rho-meson} + (p\leftrightarrow n)$$

Glauber transition operator:

$$\mathrm{O}\left(\boldsymbol{\sigma},\boldsymbol{\sigma}_n,\boldsymbol{\sigma}_p\right) = U\left(\boldsymbol{\sigma}\right) + \underbrace{\mathbf{V}_n\left(\boldsymbol{\sigma}\right)\cdot\boldsymbol{\sigma}_n + \mathbf{V}_p\left(\boldsymbol{\sigma}\right)\cdot\boldsymbol{\sigma}_p}_{\mathbf{VS}=0,\rho-meson} + W_{ij}\left(\boldsymbol{\sigma}\right)\cdot\left(\sigma_{ni}\sigma_{pj} + \sigma_{nj}\sigma_{pi}\right),$$

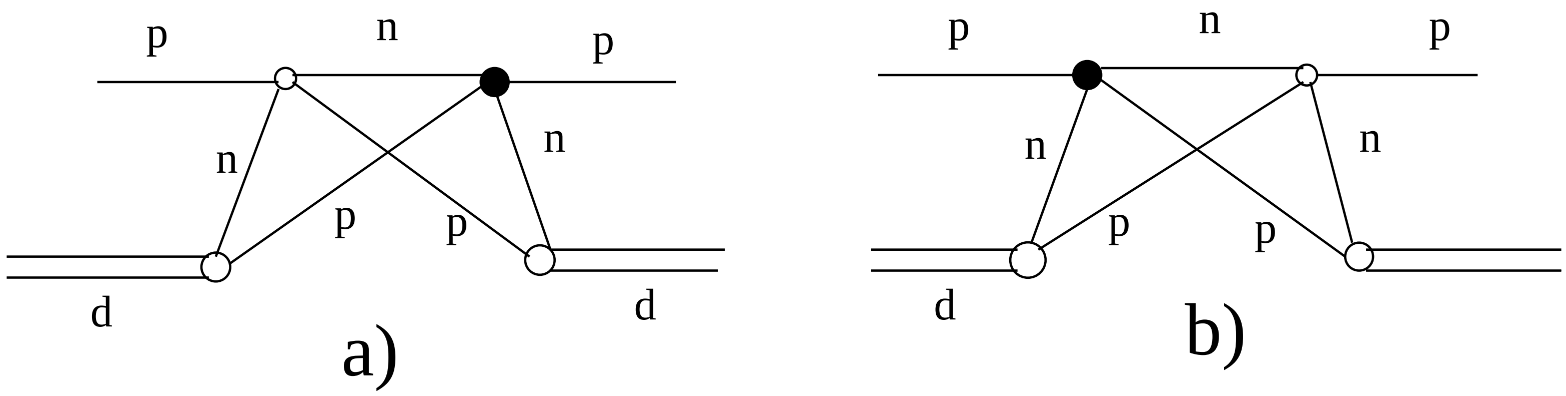
$$\int e^{i\mathbf{Q}\mathbf{r}}\Psi_d \mathrm{O} \Psi_d d^3r = US_0 + \mathbf{V}\mathbf{S}S_0^{(0)} + \left(W_{ij}\left\{S_i,S_j\right\} - W_{ii}\right)S_0^{(0)} + \ldots \qquad (9)$$

is diagonal for the beam proton spin, whereas

$$<\mu' = \frac{1}{2}, \lambda' = 0|F^{TVPC}|\mu = -\frac{1}{2}, \lambda = 1 >= i\sqrt{2}\widetilde{g}. \qquad (10)$$

Therefore, for g':

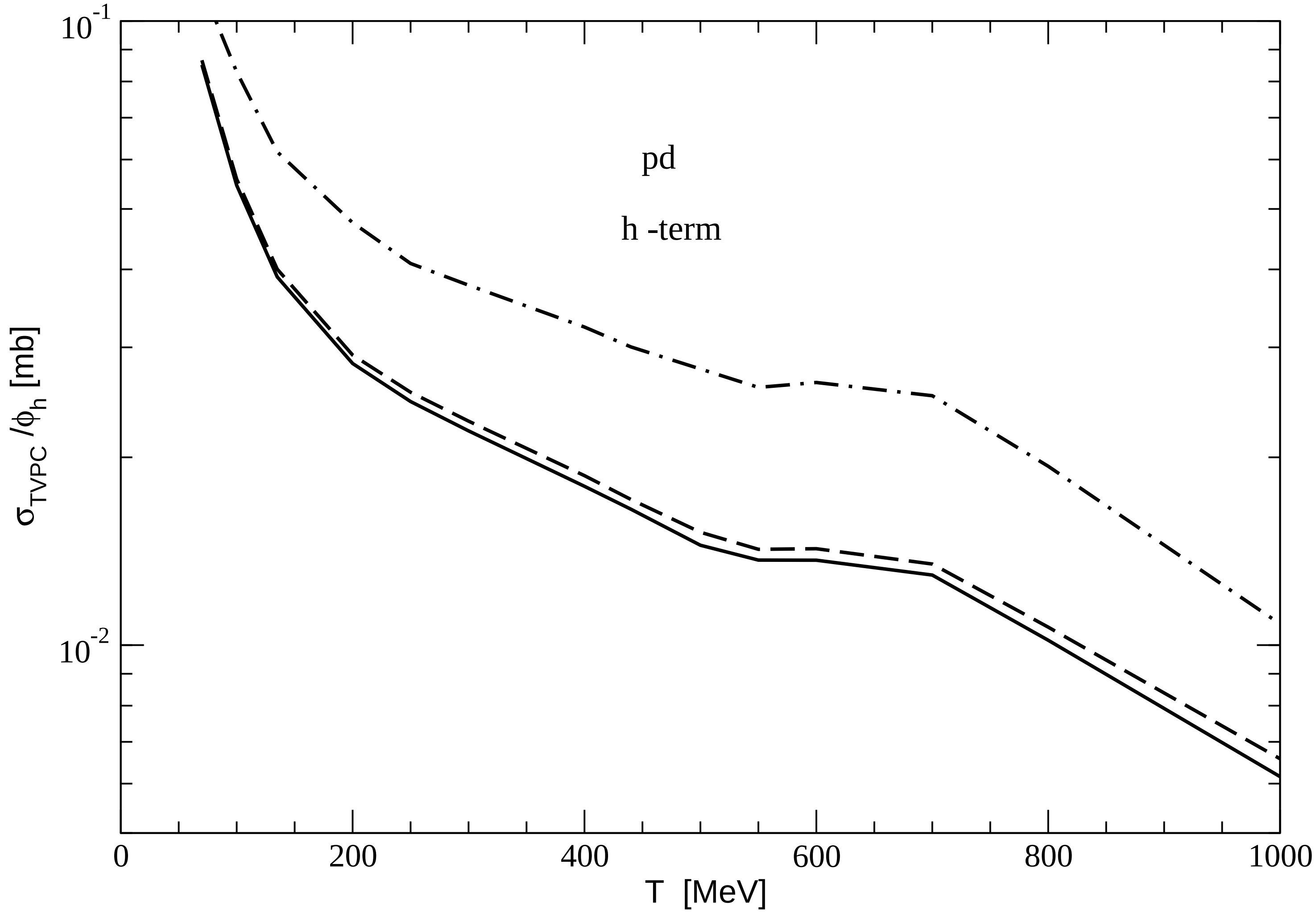
$$\widetilde{g}_5 = 0$$



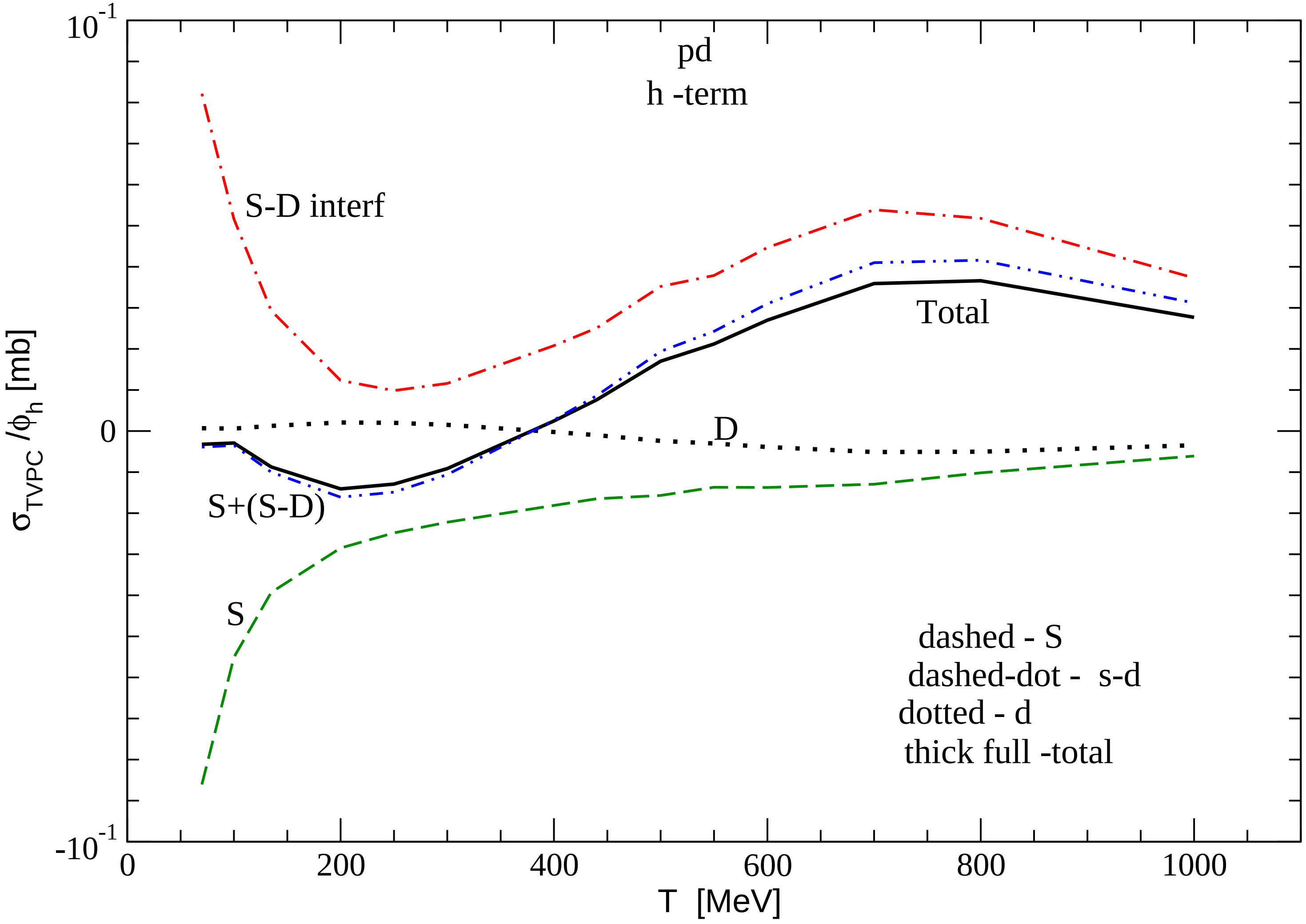
Single scattering mechanism gives zero contribution to $\widetilde{\sigma}$

TVPC. Energy dependence. Coulomb contribution

$$\widetilde{g} = \frac{ik_{pd}}{2\sqrt{\pi}} \int_0^\infty dq q^2 S_0^{(0)}(q)[C_n'(q)(h_p - g_p) + C_p'(q)(h_n - g_n)],\ C_p'(q) = C_p + \frac{q}{2M}(A_p + F_{pp}^C), \quad (11)$$



TVPC. The S- and D- wave contributions



Total polarized T-even P-even pd cross sections and restrictions to P_y^d

$$\sigma_{tot} = \sigma_0 + \sigma_1 \mathbf{p}^p \cdot \mathbf{P}^d + \sigma_2 (\mathbf{p}^p \cdot \hat{\mathbf{k}})(\mathbf{P}^d \cdot \hat{\mathbf{k}}) + \sigma_3 P_{zz} + \widetilde{\sigma} p_y^p P_{xz}^d \qquad (12)$$

$\underline{T_0 = 135\, MeV}$:

$\sigma_0 = 78.5\, mb$, $\sigma_1 = 3.7\, mb$, $\sigma_2 = 12.4\, mb$, $\sigma_3 = -1.1\, mb$

$$\frac{\sigma_1}{\sigma_0} = 0.047$$

The goal of TRIC: $\delta R_T \leq 10^{-6}$, where

$$R_T = \frac{\widetilde{\sigma}}{\sigma_0}$$

then from $\frac{P_y^d \sigma_1}{\widetilde{\sigma}} \sim 10^{-1}$ and $R_T \leq 10^{-6} \Longrightarrow {P_y}^d \leq 2 \times 10^{-6}$

The deuteron vector polarization has to be adjusted to be zero in the atomic beam source

$$A_y^p = P_y^p, \;\; A_y^d = P_y^d \tag{13}$$

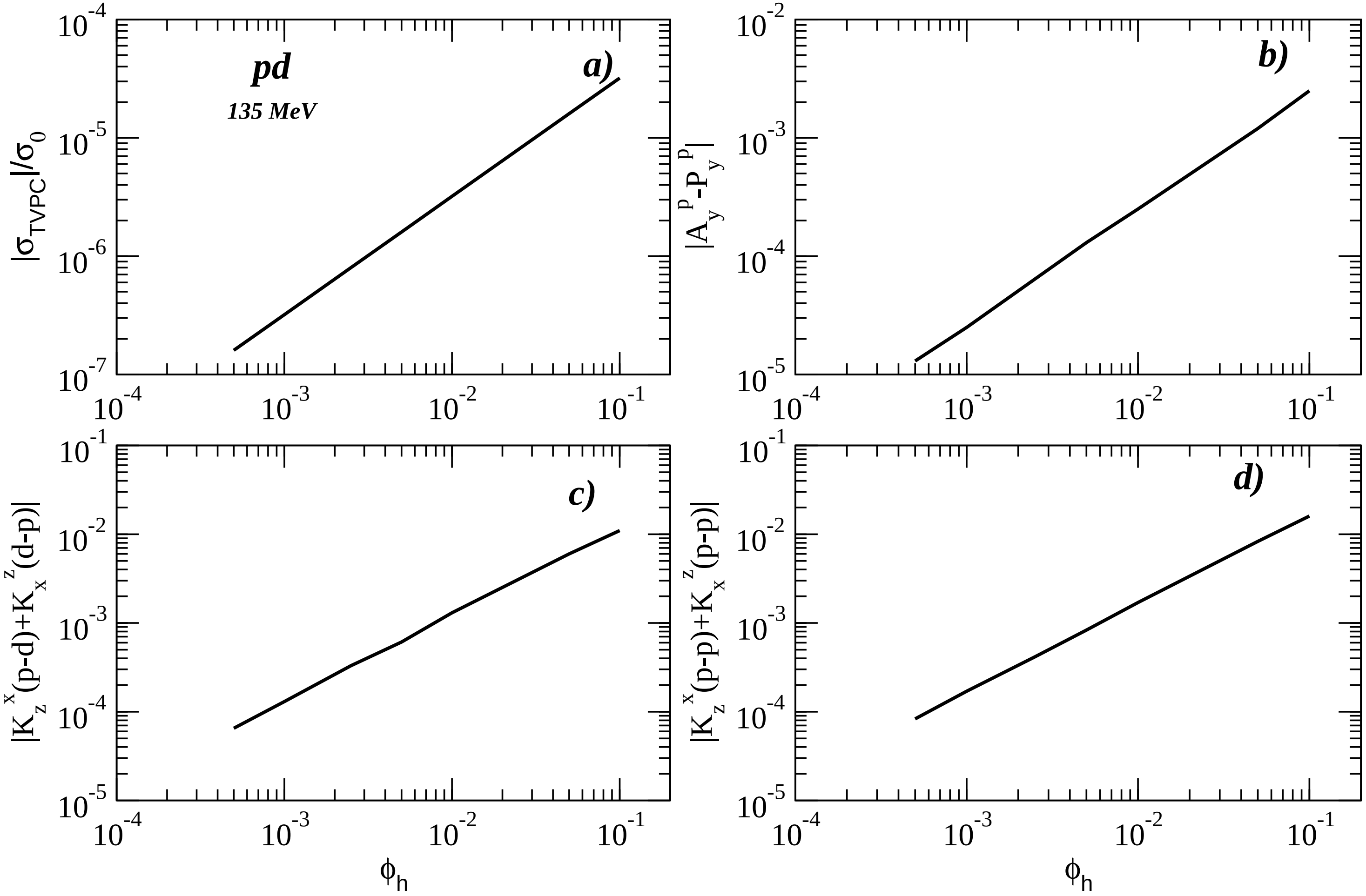
In Madison frame:

$$K_z^{x'} = K_z^x \cos\theta - K_z^z \sin\theta, \tag{14}$$
$$K_x^{z'} = K_x^z \cos\theta + K_x^x \sin\theta;$$

$$K_z^x(p \to p) = \frac{TrM\sigma_z M^+ \sigma_x}{TrMM^+}, \; K_z^x(p \to d) = \frac{TrM\sigma_z M^+ S_x}{TrMM^+},$$
$$K_z^x(d \to p) = \frac{TrMS_z M^+ \sigma_x}{TrMM^+}, \; K_z^x(d \to d) = \frac{TrMS_z M^+ S_x}{TrMM^+}.$$

$$K_x^{z'}(p \to p) = -K_z^{x'}(p \to p), \tag{15}$$
$$K_x^{z'}(p \to d) = -K_z^{x'}(d \to p),$$
$$K_x^{z'}(d \to p) = -K_z^{x'}(p \to d),$$
$$K_x^{z'}(d \to d) = -K_z^{x'}(d \to d),$$

$A_y = P_y,\ K_x^{z'} = -K_z^{x'}$



SUMMARY

- **$\widetilde{\sigma}_{tvpc}$ is a true null-test observable. Not affected by ISI&FSI, no dependence on dynamics assumptions. Will be measured by TRIC. $\widetilde{\sigma}_{tvpc}$ and uncertainties can be reasonable estimated within the Glauber model**

- Integrated polarized pd cross sections σ_1, σ_2, σ_3 are calculated $\Longrightarrow$ control of some experimental uncertainties, essential restriction on p_y^d.
- The ρ-meson contribution to $\widetilde{\sigma}_{tvpc}$ vanishes...

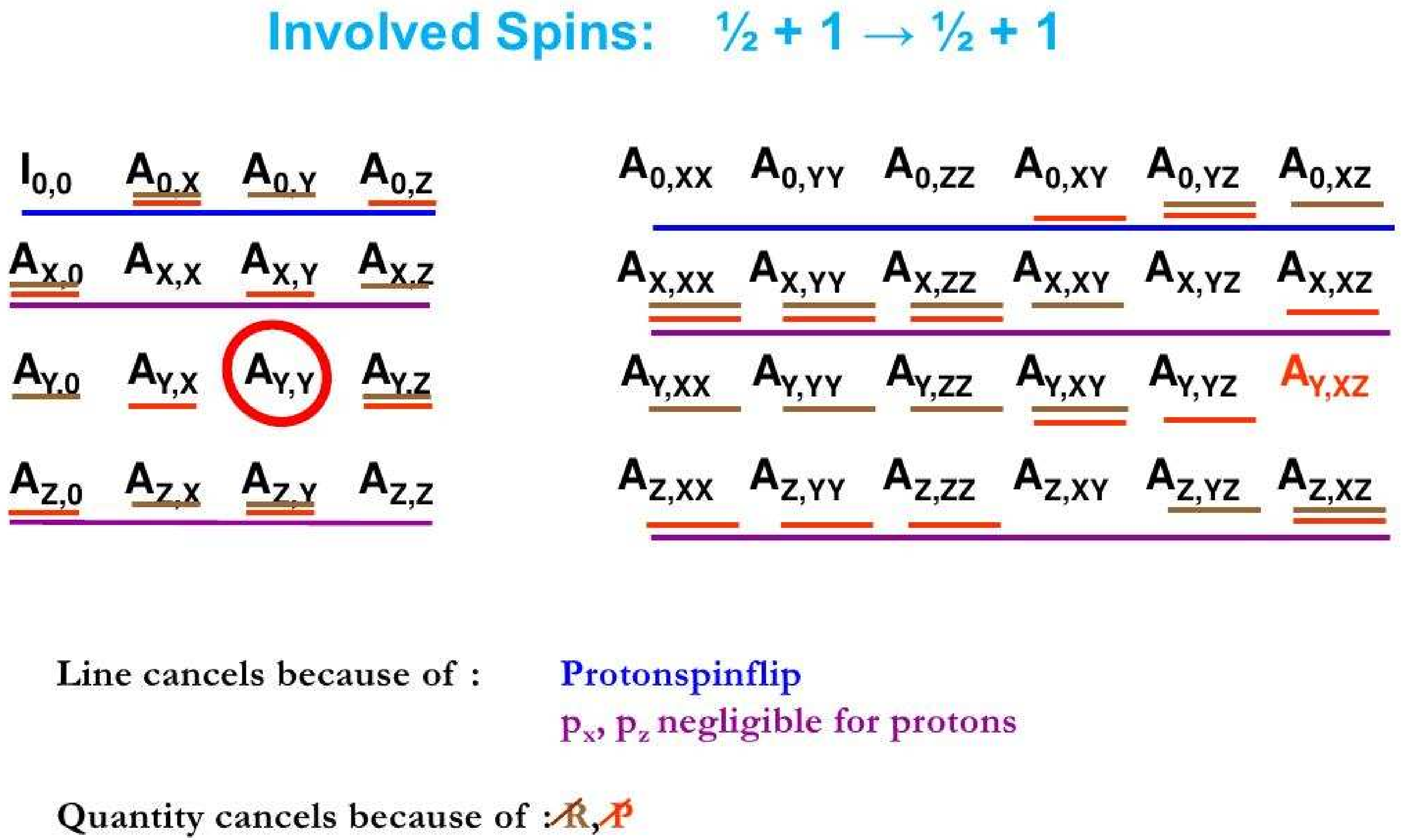
- The Coulomb interaction does not lead to divergence of the null-test observable $\widetilde{\sigma}_{tvpc}$!

- $\phi_h = \bar{G}_h/G_h < 0.001 \div 0.002$ for $\widetilde{\sigma}/\sigma_0 < 10^{-6}$
  or $|K_z^{x'}(p-d) + K_x^{z'}(d-p)| \leq 10^{-4}$
  or $|A_y^p - P_y^p| \leq 3 \times 10^{-5}$.

- ???

THANK YOU FOR ATTENTION!

Sources for false effects



From talk by D. Eversheim, ECT, (Trento, October, 2012)