XX Baldin ISHEPP
October 4, 2010

Relativistic properties of the deuteron in the Bethe-Salpeter Approach

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In Honor of the 61th Birthday of Professor V. Burov

Goals and methods

- Relativistic description of the deuteron static properties
- Relativistic description of the reactions with deuteron

- The investigations are performed within the Bethe-Salpeter formalism with separable kernel of NN-interaction

Bethe-Salpeter equation

$$T(p',p;P) = V(p',p;P) + \frac{i}{4\pi^3}\int d^4k V(p',k;P) S_2(k;P) T(k,p;P)$$

Two-particle Green function:

$$S_2^{-1}(k;P) = (\frac{1}{2}P\cdot\gamma + k\cdot\gamma - m)^{(1)}(\frac{1}{2}P\cdot\gamma - k\cdot\gamma - m)^{(2)}$$

Bethe-Salpeter amplitude:

$$\Phi^{JM}(p;P) = \frac{i}{(2\pi)^4} S_2(p;P)\int d^4k \mathrm{V}(p,k;P)\Phi^{JM}(k;P)$$

$$\Phi^{JM}(p;P) = S_2(p;P)\Gamma^{JM}(p;P)$$

Partial-wave decomposition:

$$T_{\alpha\beta,\gamma\delta}(p',p;P) = \sum_{JMab} (\mathbf{Y}_{aM}(-\mathbf{p}')\mathbf{U}_C)_{\alpha\beta} \otimes (\mathbf{U}_C \mathbf{Y}_{bM}^{+}(\mathbf{p}))_{\delta\gamma} \mathbf{T}_{ab}(p_0', |\mathbf{p}'|; p_0, |\mathbf{p}|; s)$$

$\mathbf{U}_C = \mathbf{i}\gamma^2\gamma^0$ - charge conjugation matrix

Spin-angle functions:

$$\mathbf{Y}_{JM;LS\rho}(\mathbf{p})\mathbf{U}_C = \mathbf{i}^L \sum_{m_L m_S m_1 m_2 \rho_1 \rho_2} \mathbf{C}^{S_\rho \rho}_{\frac{1}{2}\rho_1 \frac{1}{2}\rho_2} \mathbf{C}^{JM}_{Lm_L Sm_S} \mathbf{C}^{Sm_S}_{\frac{1}{2}m_1 \frac{1}{2}m_2} \mathrm{Y}_{Lm_L}(\mathbf{p}) \mathbf{u}^{\rho_1 (1)}_{m_1}(\mathbf{p}) \mathbf{u}^{\rho_2 (2)T}_{m_2}(-\mathbf{p})$$

$$\phi_a(p_0, |\mathbf{p}|) = \sum_b \mathbf{S}_{ab}(p_0, |\mathbf{p}|; s) \mathbf{g}_b(p_0, |\mathbf{p}|)$$

$$s = P^2$$

$$E_{\mathrm{p}} = \sqrt{\mathbf{p}^2 - m^2}$$

$$\mathbf{S}_{++} = \left(\sqrt{s}/2 + p_0 - E_{\mathbf{p}}\right)^{-1} \left(\sqrt{s}/2 - p_0 - E_{\mathbf{p}}\right)^{-1}$$

Separable ansatz

Interaction kernel:

$$V_{l'l}(p_0',|\mathbf{p}'|;p_0,|\mathbf{p}|;s)=\sum_{i,j=1}^{N}\lambda_{ij}(s)g_i^{[l']}(p_0',|\mathbf{p}'|)g_j^{[l]}(p_0,|\mathbf{p}|)\quad\Rightarrow$$

$$T_{l'l}(p_0',|\mathbf{p}'|;p_0,|\mathbf{p}|;s)=\sum_{i,j=1}^{N}\tau_{ij}(s)g_i^{[l']}(p_0',|\mathbf{p}'|)g_j^{[l]}(p_0,|\mathbf{p}|)$$

$$\tau_{ij}(s)=1/(\lambda_{ij}^{-1}(s)+h_{ij}(s))$$

$$h_{ij}(s)=-\frac{i}{4\pi^3}\sum_{l}\int dk_0\int \mathbf{k}^2 d|\mathbf{k}|\frac{g_i^{[l']}(k_0,|\mathbf{k}|)g_j^{[l]}(k_0,|\mathbf{k}|)}{(\sqrt{s}/2-E_k+i0)^2-k_0^2}$$

$$c_i(s)-\sum_{i,j=1}^{N}h_{ij}(s)\lambda_{kj}(s)c_j(s)=0$$

BS vertex function:

$$g_l(p_0,|\mathbf{p}|)=\sum_{i,j=1}^{N}\lambda_{ij}(s)g_i^{[l]}(p_0,|\mathbf{p}|)c_j(s)$$

Parameters of the separable kernel

$$T_{l'l}(p_0',|\mathbf{p}'|;p_0,|\mathbf{p}|;s)=\sum_{i,j=1}^{N}\tau_{ij}(s)g_i^{[l']}(p_0',|\mathbf{p}'|)g_j^{[l]}(p_0,|\mathbf{p}|)$$

singlet state:

$$T_{ll}(s)=T_{ll}(0,|\mathbf{p}^*|;0,|\mathbf{p}^*|;s)=-\frac{16\pi}{\sqrt{s}\sqrt{s-4m^2}}e^{i\delta_l}\sin\delta_l$$

$$|\mathbf{p}^*|=\sqrt{s/4-m^2}$$ - np pair relative momentum

triplet state:

$$T_{l'l}(s)=\frac{i8\pi}{\sqrt{s}\sqrt{s-4m^2}}\begin{pmatrix}\cos(2\varepsilon)e^{2i\delta_<}-1 & i\sin(2\varepsilon)e^{i(\delta_<+\delta_>)}\\ i\sin(2\varepsilon)e^{i(\delta_<+\delta_>)} & \cos(2\varepsilon)e^{2i\delta_>}-1\end{pmatrix}$$

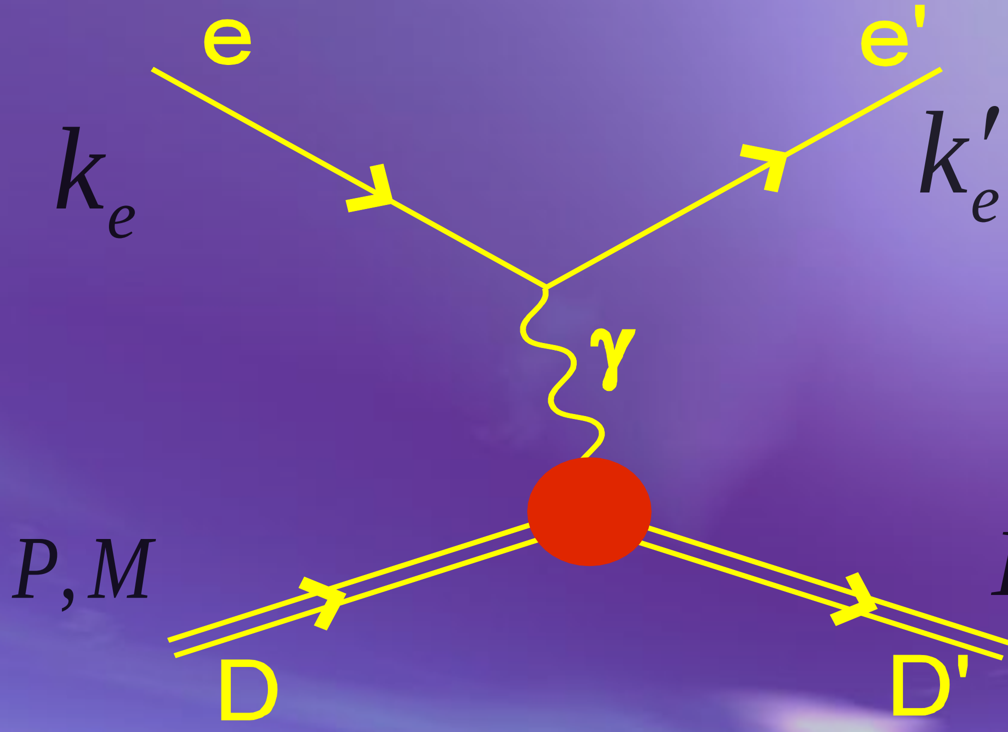
$$\delta_<=\delta_{L=J-1},\delta_>=\delta_{L=J+1}$$

$$|\mathbf{p}^*|\cot\delta_l(s)=-\frac{1}{a_0^l}+\frac{r_0^l}{2}|\mathbf{p}^*|^2+O(|\mathbf{p}^*|^3)$$

a_0^l - scattering length

r_0^l - effective range

Elastic electron-deuteron scattering



$$q = k_e - k_e' = P' - P$$

$$P' = P + q, M'$$

Cross section:

$$\frac{d\sigma}{d\Omega_e'} = \left(\frac{d\sigma}{d\Omega_e'}\right)_{Mott} \left[A\left(q^2\right) + B\left(q^2\right) \tan^2 \frac{\theta_e}{2} \right]$$

$$\left(\frac{d\sigma}{d\Omega_e'}\right)_{Mott} = \frac{\alpha^2 \cos^2 \theta_e / 2}{4E_e^2 \left(1 + 2E_e / M \sin^4 \theta_e / 2\right)}$$

Deuteron structure functions

$$A\left(q^2\right) = F_C^2\left(q^2\right) + \frac{9}{8}\eta^2 F_Q^2\left(q^2\right) + \frac{2}{3}\eta F_M^2\left(q^2\right)$$

$$B\left(q^2\right) = \frac{4}{3}\eta\left(1+\eta\right)F_M^2\left(q^2\right), \quad \eta = -\frac{q^2}{4M^2}$$

$F_C\left(q^2\right)$ - **charge form factor**

$F_Q\left(q^2\right)$ - **quadruple form factor**

$F_M\left(q^2\right)$ - **magnetic form factor**

$$F_C\left(0\right) = 1, \quad F_Q\left(0\right) = M_d^2 Q_D, \quad F_M\left(0\right) = \mu_D \frac{M_d}{m}$$

Q_D - **quadruple moment** $\quad$ μ_D - **magnetic moment**

Amplitude of the *eD* scattering

$$M_{fi} = ie^2 \bar{u}_{m'}(k'_e)\gamma_\mu u_m(k_e)\frac{1}{q^2}\langle D'M'|j_\mu|DM\rangle$$

$u_m(k_e)$ - spinor of the free electron

Electromagnetic current:

$$\langle D'M'|j_\mu|DM\rangle = -\xi^*_{\alpha M'}(P')\xi_{\beta M}(P)\times$$
$$\times\left\{(P'_\mu + P_\mu)\left[g^{\alpha\beta}F_1(q^2) - \frac{q^\alpha q^\beta}{2M_d^2}F_2(q^2)\right] - (q^\alpha g^\beta_\mu - q^\beta g^\alpha_\mu)G_1(q^2)\right\}$$

$\xi_M(\xi^*_{M'})$ - polarization 4-vector of the initial (scattered) deuteron

Normalization condition: $\lim_{q^2\to 0}\langle D'M'|j_\mu|DM\rangle = 2P_\mu\delta_{MM'}.$

$$F_C = F_1 + \frac{2}{3}\eta\left[F_1 + (1+\eta)F_2 - G_1\right]$$

$$F_Q = F_1 + (1+\eta)F_2 - G_1$$

$$F_M = G_1$$

$$F_C = \frac{1}{2M}\frac{\langle M'=0|j_0|M=0\rangle + 2\langle M'=1|j_0|M=1\rangle}{3(1+\eta)}$$

$$F_Q = \frac{1}{2M}\frac{\langle M'=0|j_0|M=0\rangle - \langle M'=1|j_0|M=1\rangle}{1+\eta}$$

$$F_M = \frac{\sqrt{2}}{2M}\frac{\langle M'=1|j_x|M=0\rangle}{\sqrt{\eta}\sqrt{1+\eta}}$$

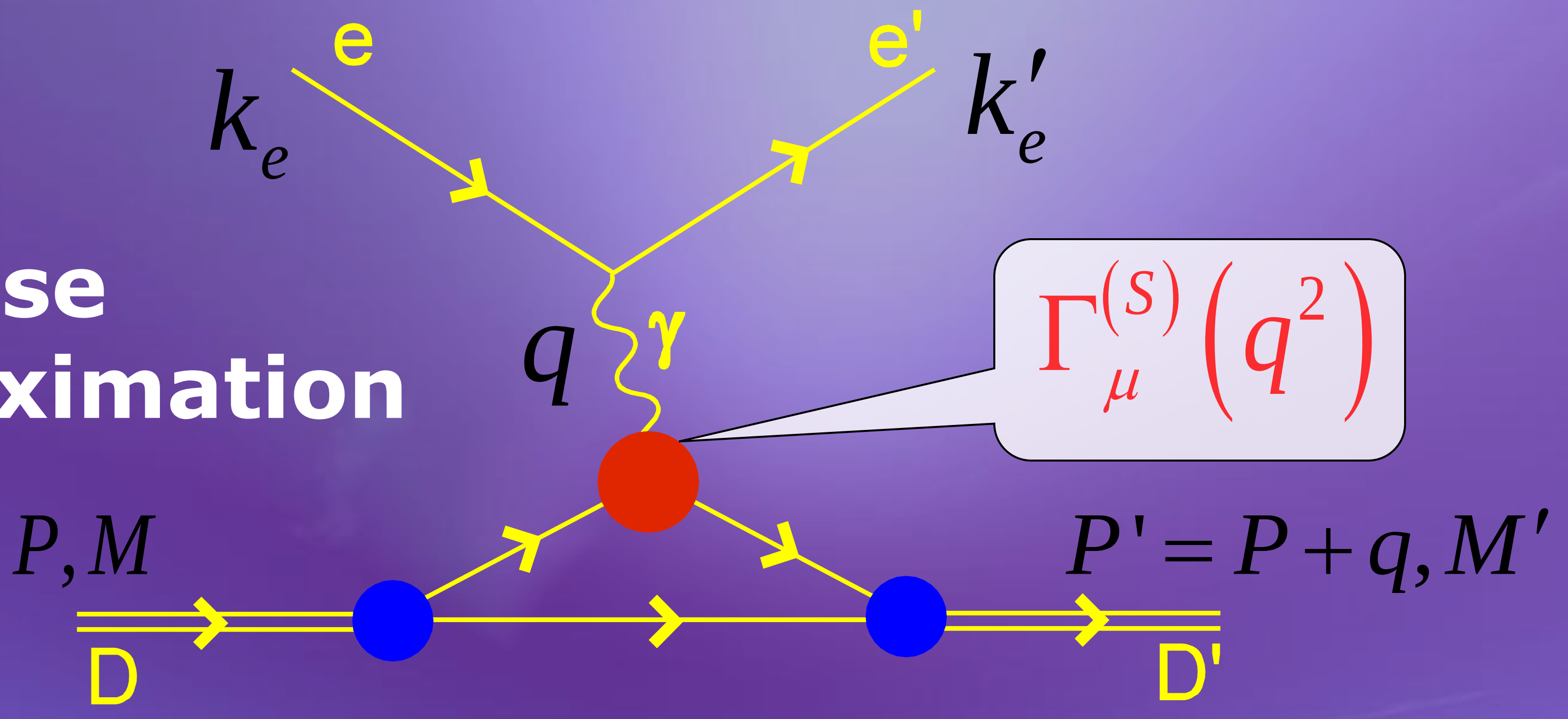
Deuteron polarization tensor

$$T_{20}\left[A+B\tan^2\frac{\theta_e}{2}\right]=-\frac{1}{\sqrt{2}}\left\{\frac{8}{3}\eta F_C F_Q+\frac{9}{8}\eta^2 F_Q^2\left(q^2\right)+\frac{1}{3}\eta\left[1+2\left(1+\eta\right)\tan^2\frac{\theta_e}{2}\right]F_M^2\right\}$$

$$T_{21}\left[A+B\tan^2\frac{\theta_e}{2}\right]=\frac{2}{\sqrt{3}}\eta\sqrt{\eta+\eta^2\sin^2\frac{\theta_e}{2}}F_M F_Q\sec^2\frac{\theta_e}{2}$$

$$T_{22}\left[A+B\tan^2\frac{\theta_e}{2}\right]=-\frac{1}{2\sqrt{3}}\eta F_M^2$$

Impulse approximation



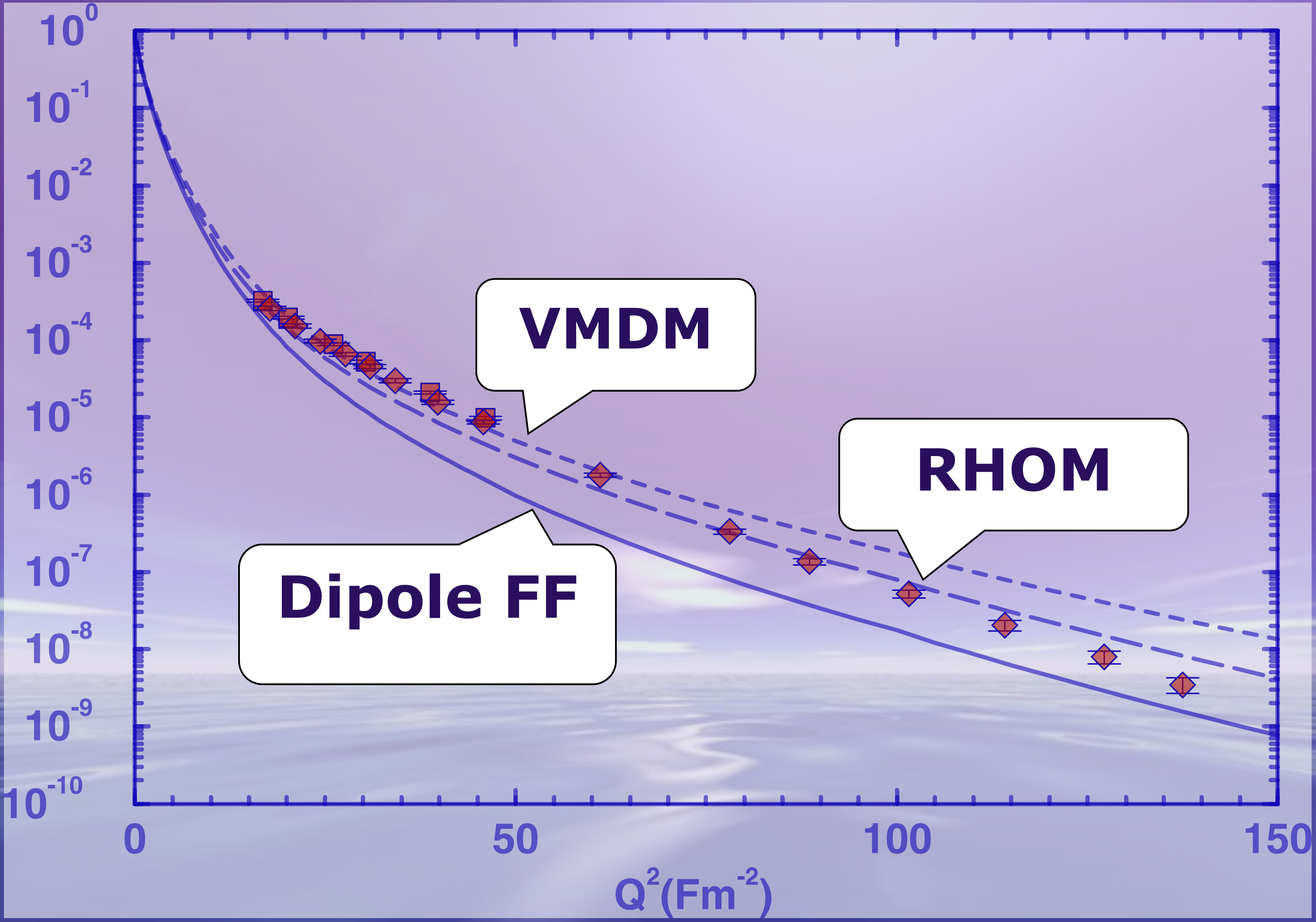
$$\left\langle D'M' \middle| j_\mu \middle| DM \right\rangle = i \int \frac{dp}{(2\pi)^4} \mathrm{Tr}\left\{ \bar{\chi}_{M'}\left(P', p'\right) \Gamma_\mu^{(S)}\left(q^2\right) \chi_M\left(P, p\right) \left(\frac{(P\gamma)}{2} - (p\gamma) + m \right) \right\}$$

Interaction vertex:

isoscalar

$$\Gamma_\mu^{(S)}\left(q^2\right) = \gamma_\mu F_1^{(S)}\left(q^2\right) - \frac{\gamma_\mu (q\gamma) - (q\gamma)\gamma_\mu}{4m} F_2^{(S)}\left(q^2\right)$$

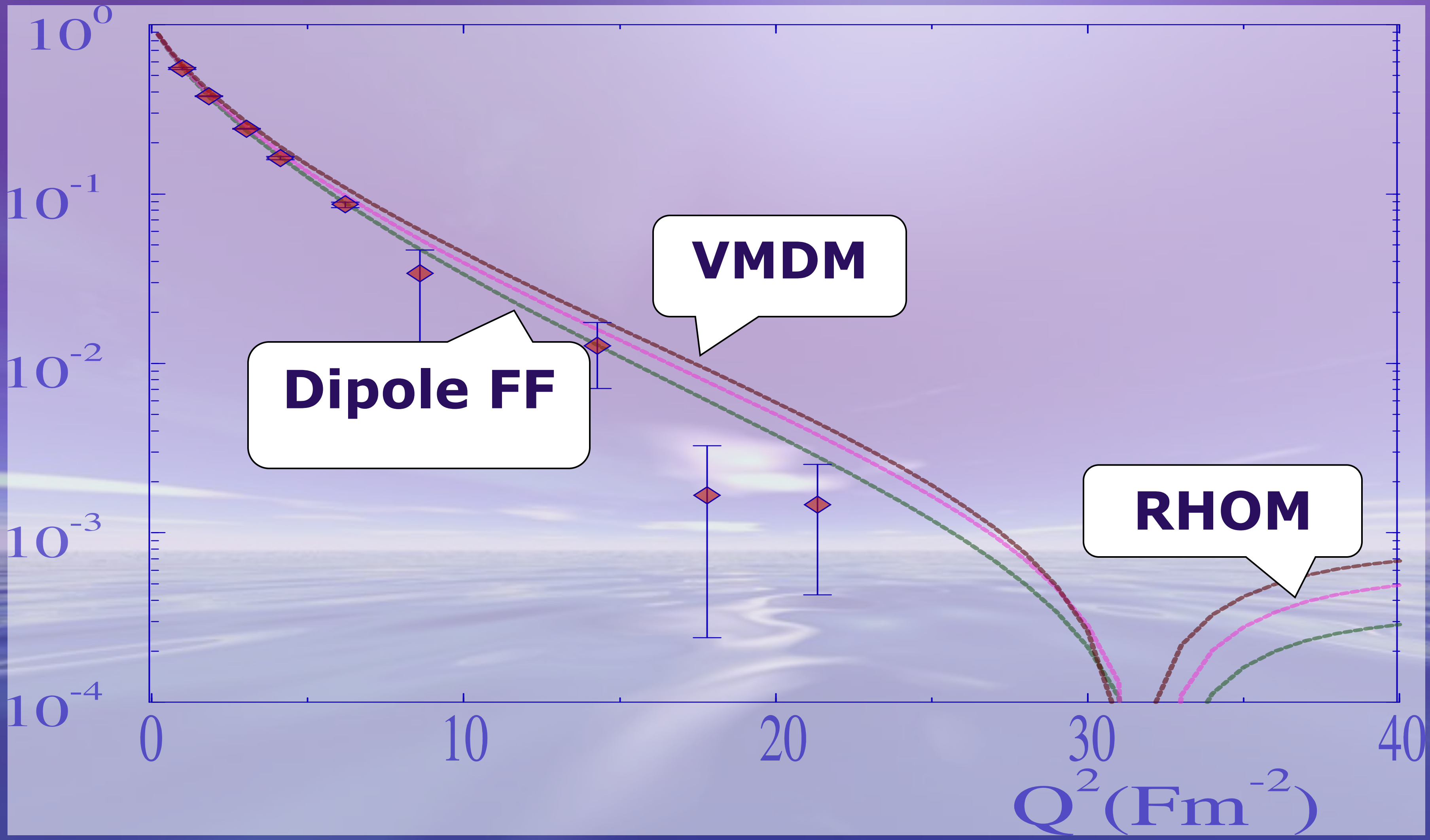
$A(Q^2)$



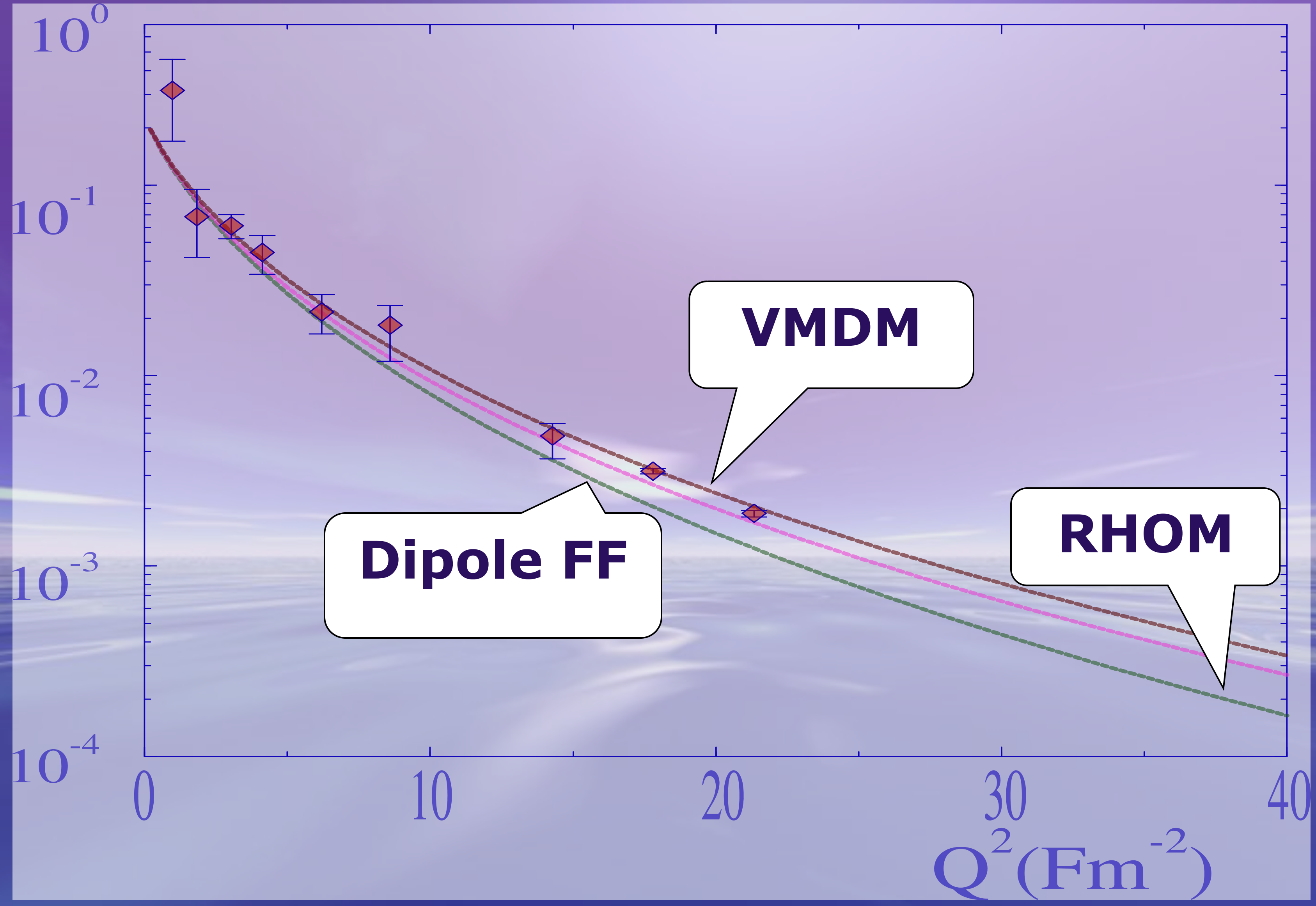
Model kernel – relativistic Graz II:
G. Rupp, J.A. Tjon, Phys. Rev. C 45 (1992) 2133-2142

- Dipole FF – dipole fit
- VMDM – vector meson dominance model
- RHOM – relativistic harmonic-oscillator model

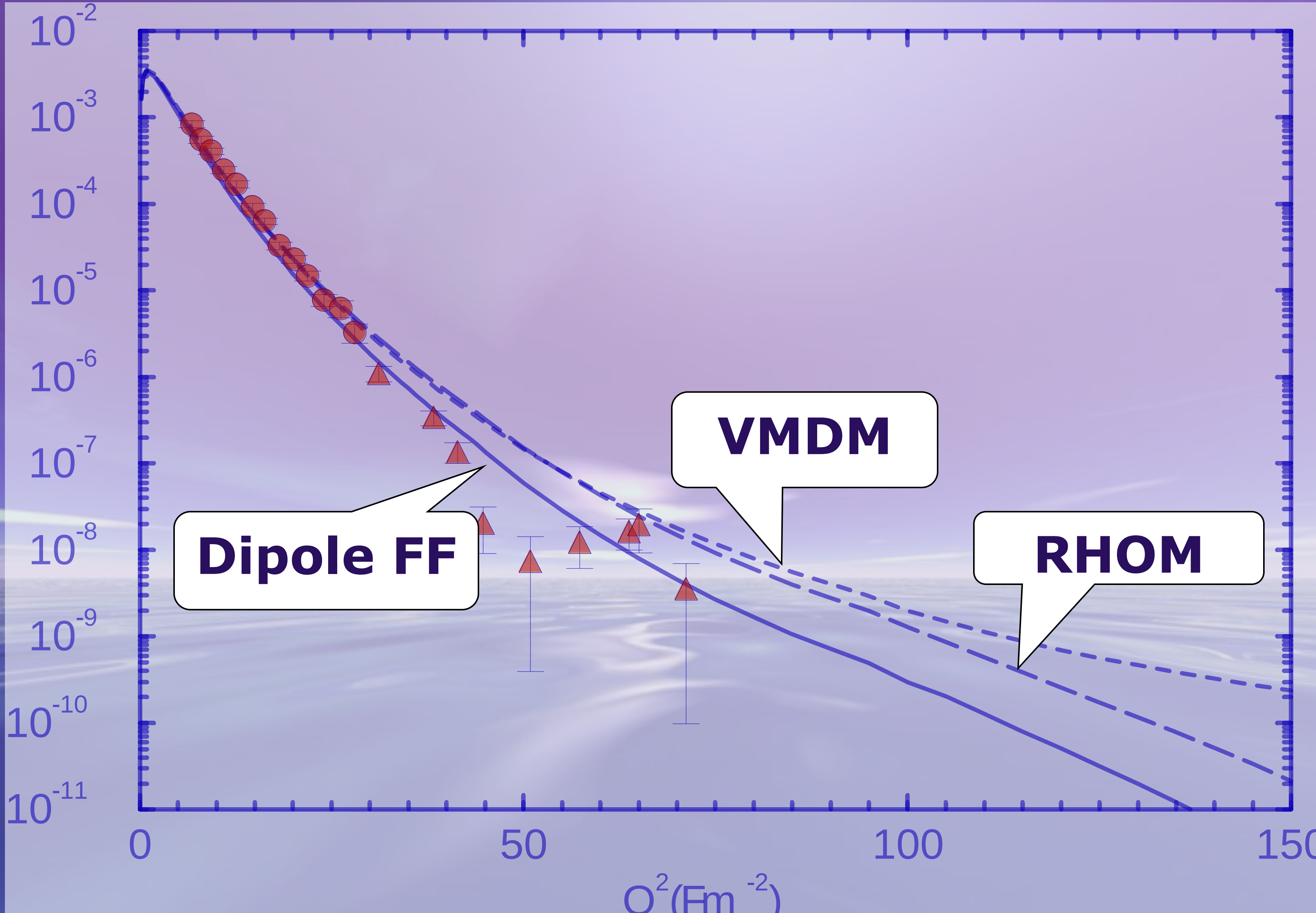
$F_C(Q^2)$



$F_Q(Q^2)$



$B(Q^2)$



10-2
10-3
10-4
10-5
10-6
10-7
10-8
10-9
10-10
10-11
0
50
100
150
Q2(Fm-2)
VMDM
Dipole FF
RHOM

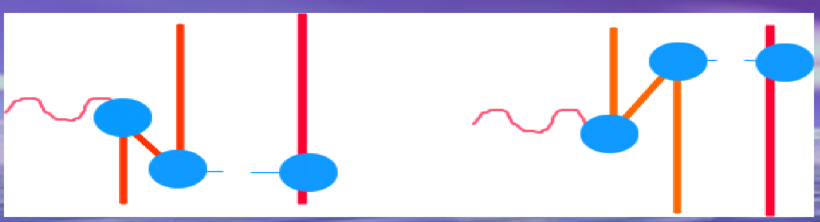
Relativistic Deuteron structure:

$^3S_1^{++}$, $^3D_1^{++}$ - have nonrelativistic limit

$^3P_1^{+-}$, $^3P_1^{-+}$, $^1P_1^{+-}$, $^1P_1^{-+}$, $^3S_1^{--}$, $^3D_1^{--}$

S.G. Bondarenko, V.V. Burov, S.M. Dorkin, Phys. Rev. C 58 (1998) P. 3143

Pair currents:



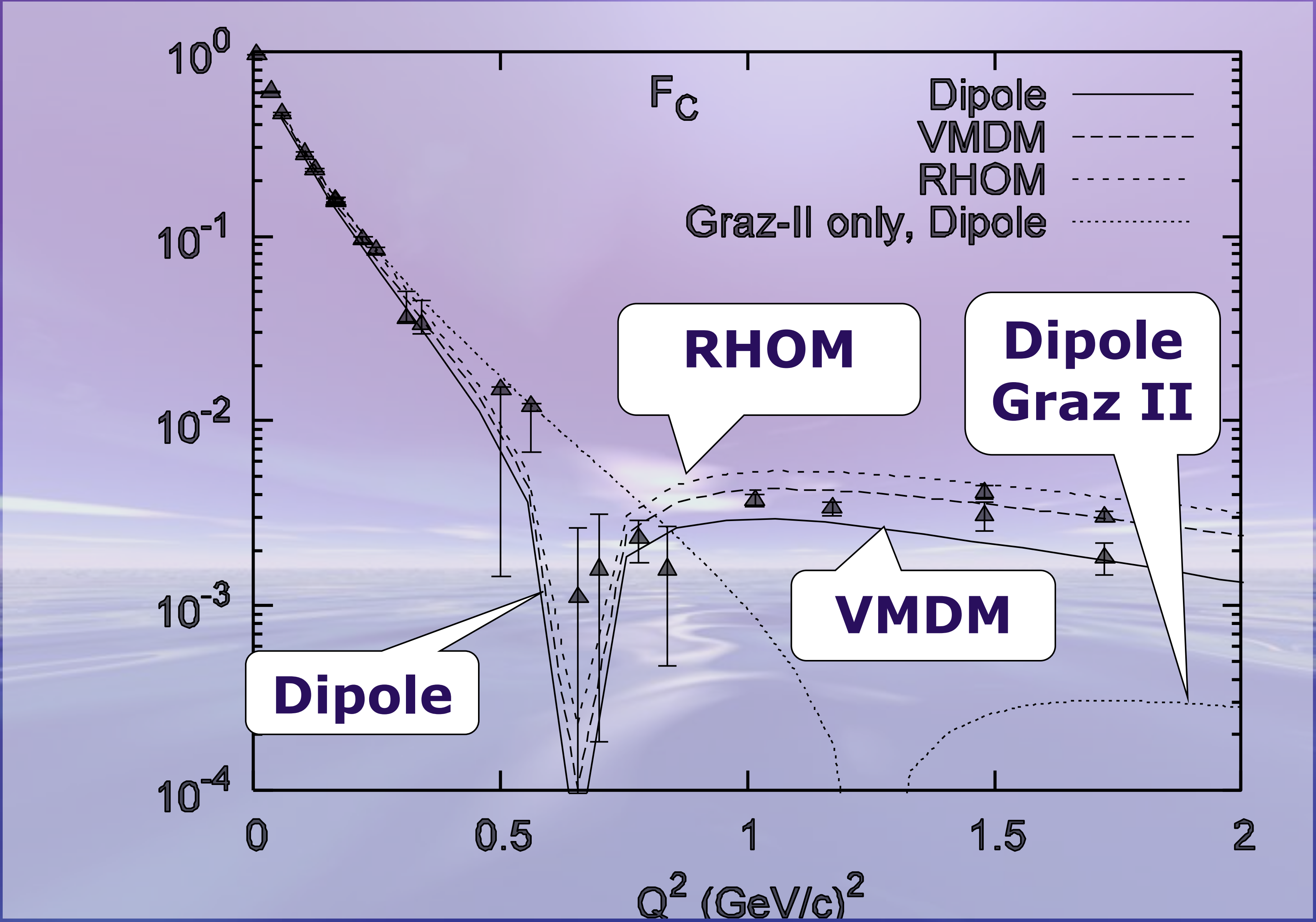
P waves

Y. Manabe, A. Hosaka, H. Toki, arXiv:0705.3497[nucl-th]

P waves -> fit to F_C

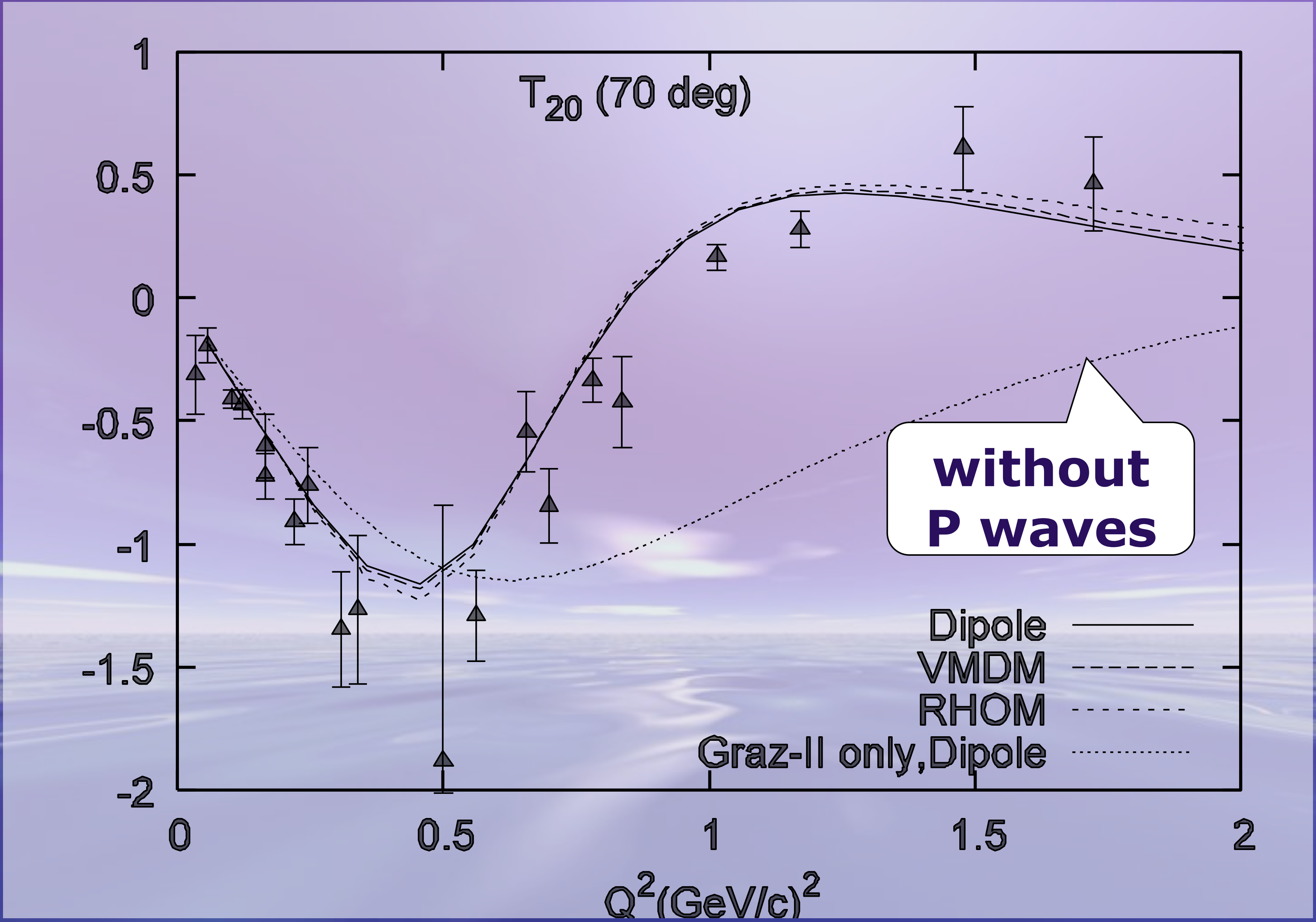
$F_C(Q^2)$

+ P wave



10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
F_C
Dipole
VMDM
RHOM
Graz-II only, Dipole
RHOM
Dipole Graz II
VMDM
Dipole
0
0.5
1
1.5
2
Q^2 (GeV/c)^2

+ P wave



T$_{20}$ (70 deg)
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2
Q^2(GeV/c)^2
without P waves
Dipole
VMDM
RHOM
Graz-II only,Dipole

Elastic electron-deuteron scattering

- **Form factors, structure functions, deuteron polarization tensor were calculated within the Bethe-Salpeter approximation with the separable Graz II kernel of interaction**
- **The suffitient influence of used models for elastic form factors on the charge, quadruple and magnetic form factors is shown**
- **The effect of including P waves into the calculation of the form factors and the polarization tensor is significant**

S.G. Bondarenko et.al., Prog. Part. Nucl. Phys. 48 (2002) 449; nucl-th/0203069

- Deuteron photodisintegration
- Deuteron electrodisintegration
  a) small energies - successfully
  b) high energies - problems

Form factors of type $g(p) \sim \frac{1}{(p_0^2 - \mathbf{p}^2 - \beta^2)^n}$, limits of applicability

$$h_{ij}(s) = -\frac{i}{4\pi^3}\sum_l \int dp_0 \int \mathbf{p}^2 d|\mathbf{p}| \frac{g_i^{[l']}(p_0,|\mathbf{p}|) g_j^{[l]}(p_0,|\mathbf{p}|)}{(\sqrt{s}/2 - E_p + i0)^2 - p_0^2}$$

Nonintegrable singularities:

$\sqrt{s}/2 - E_p = \sqrt{\mathbf{p}^2 + \beta^2}$ at $\mathbf{p} = 0$ $\Rightarrow$ $s \le 4(m+\beta)^2$

Graz II : $s \le 4.8086\,\mathrm{GeV}^2$ $\Rightarrow$

$s/4 - m^2 = mT_{lab}/2$ $\Rightarrow$ $T_{lab} \le 682.9\,\mathrm{MeV}$

In photobreakup: $\mathrm{E}_\gamma = \mathrm{T}_{lab}/2 \le 340\mathrm{MeV}$

Relativistic generalization

Yamaguchi-type form factor:

$$g(|\mathbf{p}|) = \frac{1}{\mathbf{p}^2 + \beta^2}$$

$$\mathbf{p}^2 \to -p^2 = -p_0^2 + \mathbf{p}^2 \Rightarrow g_p(p) = \frac{1}{-p^2+\beta^2} \xrightarrow{center-of-mass} \frac{1}{-p_0^2+\mathbf{p}^2+\beta^2+i0}$$

$$g_p \to p_0 = \pm\sqrt{\mathbf{p}^2+\beta^2} \mp i0$$

Y. Avishai, T. Mizutani, Nucl. Phys. A 338 (1980) 377-412

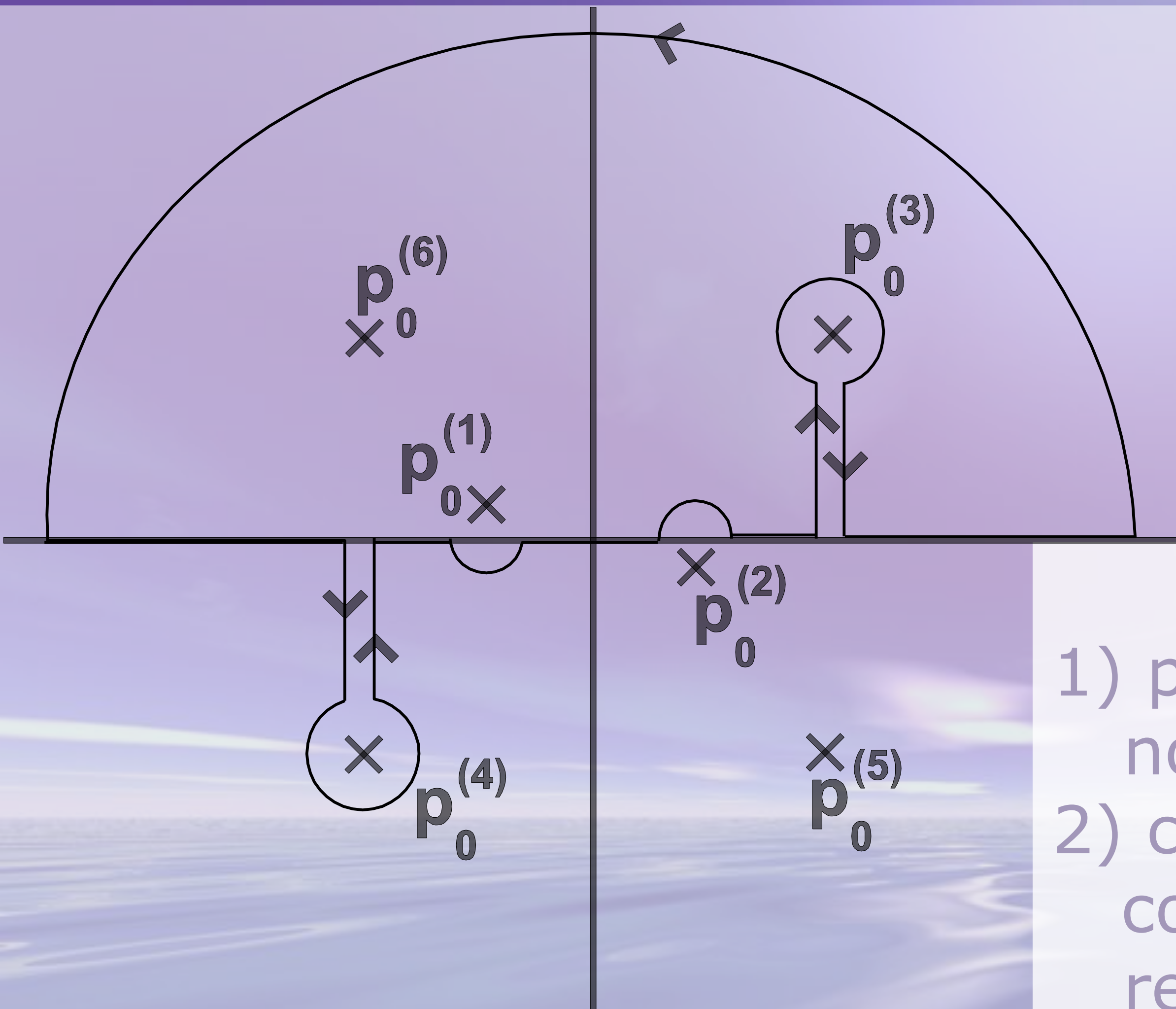
$$Q = p - \frac{P\cdot p}{s}P \Rightarrow g_Q(p) = \frac{1}{-Q^2+\beta^2} \xrightarrow{center-of-mass} \frac{1}{\mathbf{p}^2+\beta^2}$$

$$g_Q \to \textbf{no poles}$$

K. Schwarz, J. Frohlich, H.F.K. Zingl, L. Streit, Acta Phys. Austr. 53 (1981) 191-202

$$g_p(p) = \frac{1}{(p_0^2 - \mathbf{p}^2 - \beta^2)^2 + \alpha^4}$$

Contour of integration



$$p_0^{(1,2)} = \pm\sqrt{s}/2 \mp E_p \pm i\varepsilon$$

$$p_0^{(3,4)} = \pm\sqrt{\mathbf{p}^2 + \beta^2 + i\alpha^2}$$

$$p_0^{(5,6)} = \pm\sqrt{\mathbf{p}^2 + \beta^2 - i\alpha^2}$$

α→0:

1) poles move but do not cross the contour
2) correct limit: coincidence with the result obtained using standard form factors
3) unitarity for the S-matrix

R.E. Cutkosky, P.V. Landshoff, D.I. Olive, J.C. Polkinghorne, Nucl. Phys. B 12 (1969) 281-300

Form factors and kernels (minimal choice)

Uncoupled channels:

$^3P_0, ^1P_1, ^3P_1$ (rank-II kernel):

$$g_1^{[P]}(p) = \frac{\sqrt{-p_0^2 + \mathbf{p}^2}}{(p_0^2 - \mathbf{p}^2 - \beta_1^2)^2 + \alpha_1^4}$$

$$g_2^{[P]}(p) = \frac{\sqrt{(-p_0^2 + \mathbf{p}^2)^3}(p_{c2} - p_0^2 + \mathbf{p}^2)}{((p_0^2 - \mathbf{p}^2 - \beta_2^2)^2 + \alpha_2^4)^2}$$

$^1S_0$ (rank-III kernel):

$$g_1^{[S]}(p) = \frac{(p_{c1} - p_0^2 + \mathbf{p}^2)}{(p_0^2 - \mathbf{p}^2 - \beta_1^2)^2 + \alpha_1^4}$$

$$g_2^{[S]}(p) = \frac{(p_0^2 - \mathbf{p}^2)(p_{c2} - p_0^2 + \mathbf{p}^2)^2}{((p_0^2 - \mathbf{p}^2 - \beta_2^2)^2 + \alpha_2^4)^2}$$

$$g_3^{[S]}(p) = \frac{(p_0^2 - \mathbf{p}^2)}{(p_0^2 - \mathbf{p}^2 - \beta_3^2)^2 + \alpha_3^4}$$

Coupled channel: $^3S_1$-$^3D_1$ (rank-VI kernel):

$$g_1^{[S]}(p) = -\frac{(p_{c1} - p_0^2 + \mathbf{p}^2)}{(p_0^2 - \mathbf{p}^2 - \beta_1^2)^2 + \alpha_1^4}$$

$$g_2^{[S]}(p) = -\frac{(p_0^2 - \mathbf{p}^2)(p_{c2} - p_0^2 + \mathbf{p}^2)^2}{((p_0^2 - \mathbf{p}^2 - \beta_2^2)^2 + \alpha_2^4)^2}$$

$$g_3^{[D]}(p) = \frac{(p_0^2 - \mathbf{p}^2)(p_{c3} - p_0^2 + \mathbf{p}^2)^2}{((p_0^2 - \mathbf{p}^2 - \beta_{31}^2)^2 + \alpha_{31}^4)((p_0^2 - \mathbf{p}^2 - \beta_{32}^2)^2 + \alpha_{32}^4)}$$

$$g_4^{[D]}(p) = \frac{(p_0^2 - \mathbf{p}^2)}{(p_0^2 - \mathbf{p}^2 - \beta_4^2)^2 + \alpha_4^4}$$

$$g_3^{[S]}(p) = g_4^{[S]}(p) = g_1^{[D]}(p) = g_2^{[D]}(p) = 0$$

Deuteron vertex functions:

$$g_{^3S_1^+}(p) = (c_1\lambda_{11} + c_2\lambda_{12} + c_3\lambda_{13} + c_4\lambda_{14}) g_1^{[S]}(p) + (c_1\lambda_{11} + c_2\lambda_{22} + c_3\lambda_{23} + c_4\lambda_{24}) g_2^{[S]}(p)$$

$$g_{^3D_1^+}(p) = (c_1\lambda_{13} + c_2\lambda_{23} + c_3\lambda_{33} + c_4\lambda_{34}) g_3^{[D]}(p) + (c_1\lambda_{14} + c_2\lambda_{24} + c_3\lambda_{34} + c_4\lambda_{44}) g_4^{[D]}(p)$$

Normalization:

$$p_l = \frac{i}{2M_d(2\pi)^4} \int dk_0 \int \mathbf{k}^2 d|\mathbf{k}| \frac{(E_k - M_d/2)[g_l(k_0, |\mathbf{k}|)]^2}{((M_d/2 - E_k + i0)^2 - k_0^2)^2}$$

Calculations

Analisys:

1) No sign change, no bound state

$^1P_1{}^+, {}^3P_1{}^+$:

$$\lambda_{ij}(s) = \bar{\lambda}_{ij} = const$$

2) Sign change, no bound state

$^1S_0{}^+, {}^3P_0{}^+$:

$$\lambda_{ij}(s) = (s_0 - s)\bar{\lambda}_{ij}$$

3) Bound state

$^3S_1{}^+ - {}^3D_1{}^+$:

$$\det|\tau_{ij}^{-1}(s = M_d)| = 0 \rightarrow \lambda_{ij}(s) = \frac{\bar{\lambda}_{ij}}{s - m_0^2}$$

Minimization:

P waves:

$$\chi^2 = \sum_{i=1}^{n} (\delta^{\exp}(s_i) - \delta(s_i))^2 / (\Delta\delta^{\exp}(s_i))^2$$

$^1S_0^+$:

$$\chi^2 = \sum_{i=1}^{n} (\delta^{\exp}(s_i) - \delta(s_i))^2 / (\Delta\delta^{\exp}(s_i))^2 + (a^{\exp} - a)^2 / (\Delta a^{\exp})^2$$

$^3S_1^+$–$^3D_1^+$:

$$\chi^2 = \sum_{i=1}^{n} (\delta_S^{\exp}(s_i) - \delta_S(s_i))^2 / (\Delta\delta_S^{\exp}(s_i))^2 + (\delta_D^{\exp}(s_i) - \delta_D(s_i))^2 / (\Delta\delta_D^{\exp}(s_i))^2$$

$$+ (\varepsilon^{\exp}(s_i) - \varepsilon(s_i)) / (\Delta\varepsilon^{\exp}(s_i))^2 + (a^{\exp} - a)^2 / (\Delta a^{\exp})^2$$

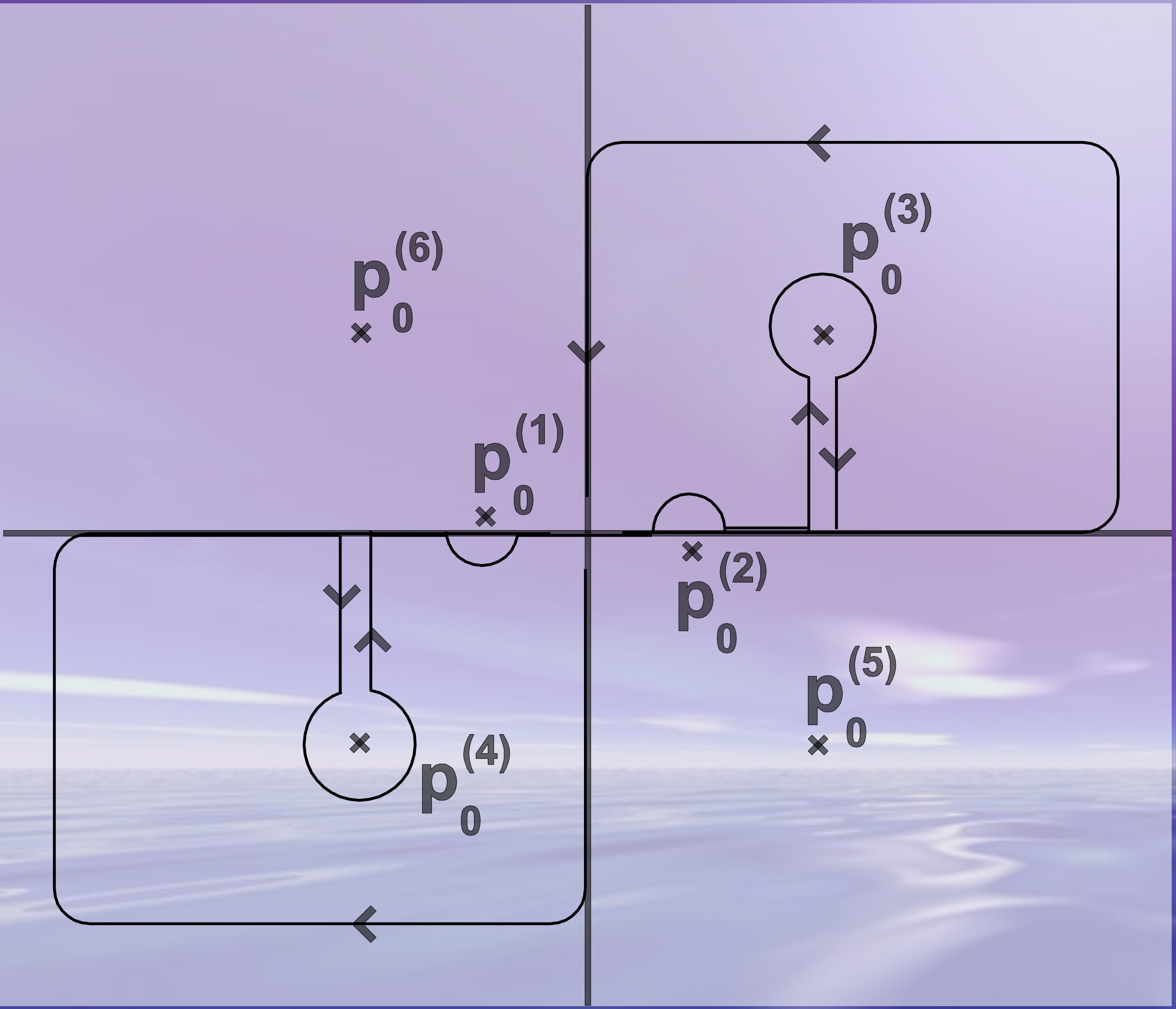
Two independent ways of calculation

1) Integration over p_0 using the Cauchy theorem, numerical integration over $|p|$

2) Integration over p_0 using the Wick rotation, numerical calculations

Wick rotation:

$$p_0 \rightarrow \boldsymbol{i}p_4$$



J. Fleischer, J.A. Tjon, Nucl. Phys. B 84 (1975) 375

Results and comparison with experiment

$^{1}S_{0}^{+}$:

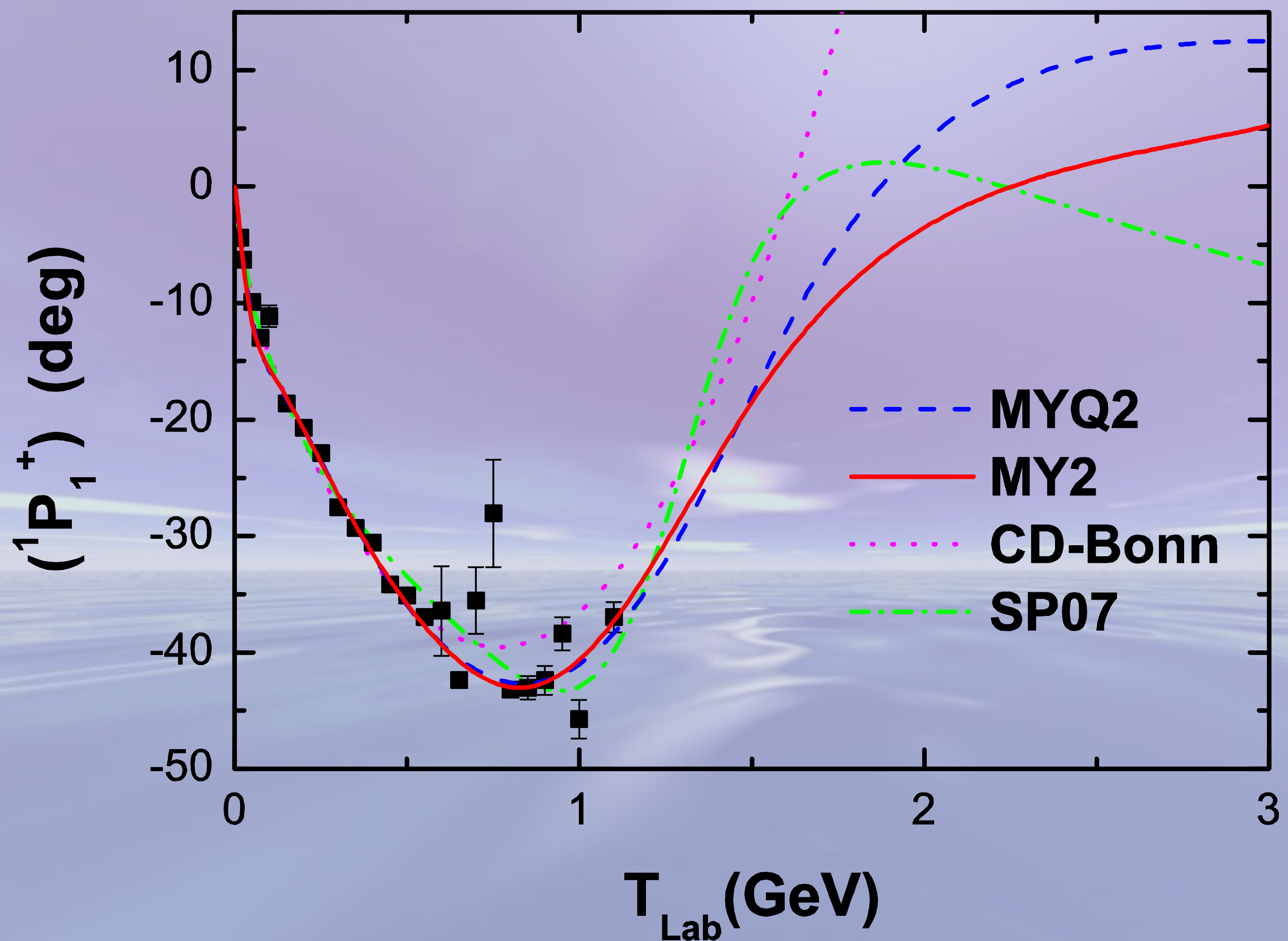
	a_s (fm)	r_{0s} (fm)
MY3	-23.750	2.70
MYQ3	-23.754	2.78
Experiment	-23.748(10)	2.75(5)

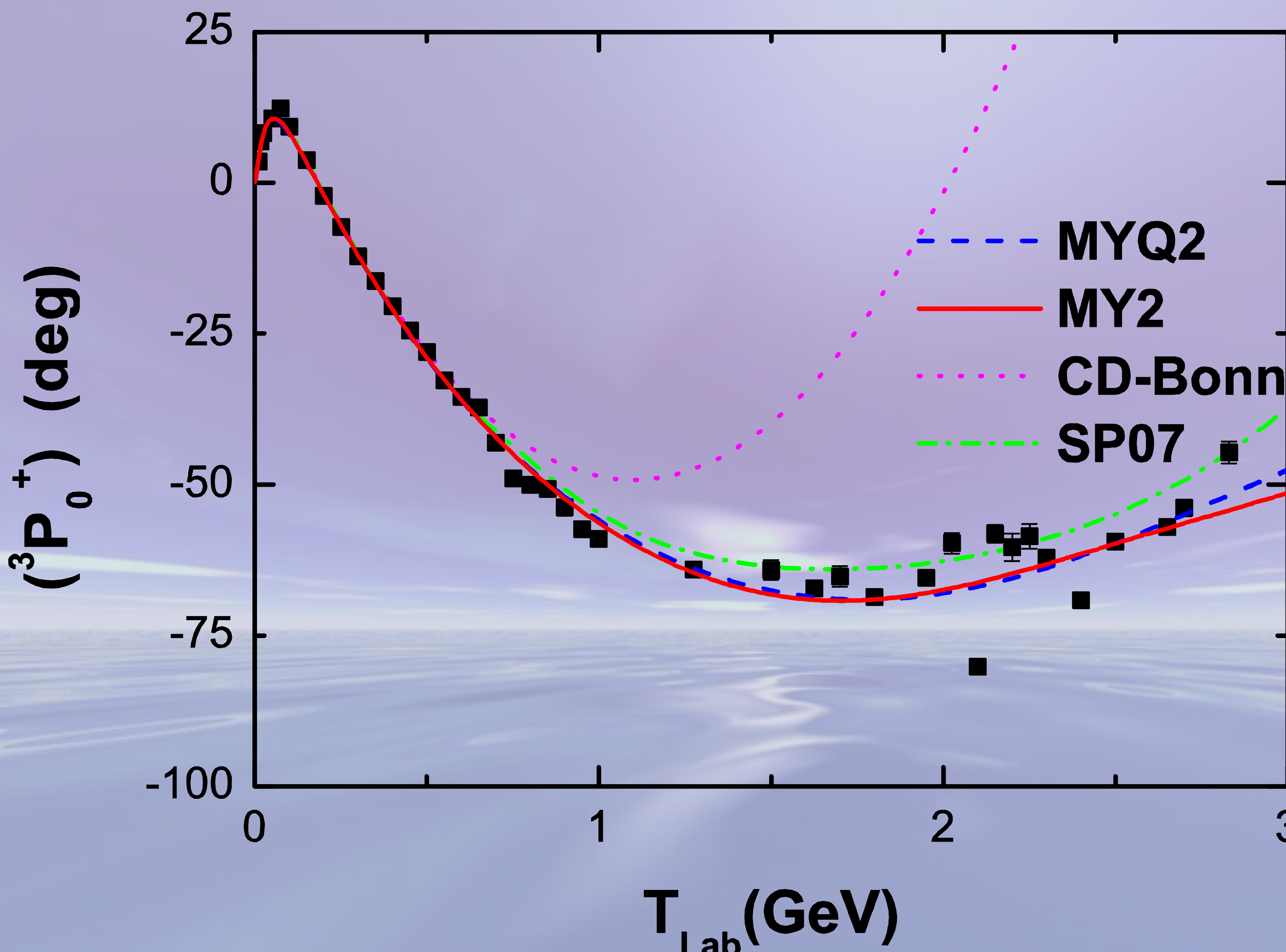
$^{3}S_{1}^{+}$–$^{3}D_{1}^{+}$:

	p_d(%)	a_t(fm)	r_{0t}(fm)	E_d(MeV)
MY4	6	5.417	1.75	2.2246
MYQ4	6	5.417	1.75	2.2246
CD-Bonn	4.85	5.4196	1.751	2.224575
Graz II	4.82	5.42	1.78	2.225
Experiment	-	5.424(4)	1.759(5)	2.224644(46)

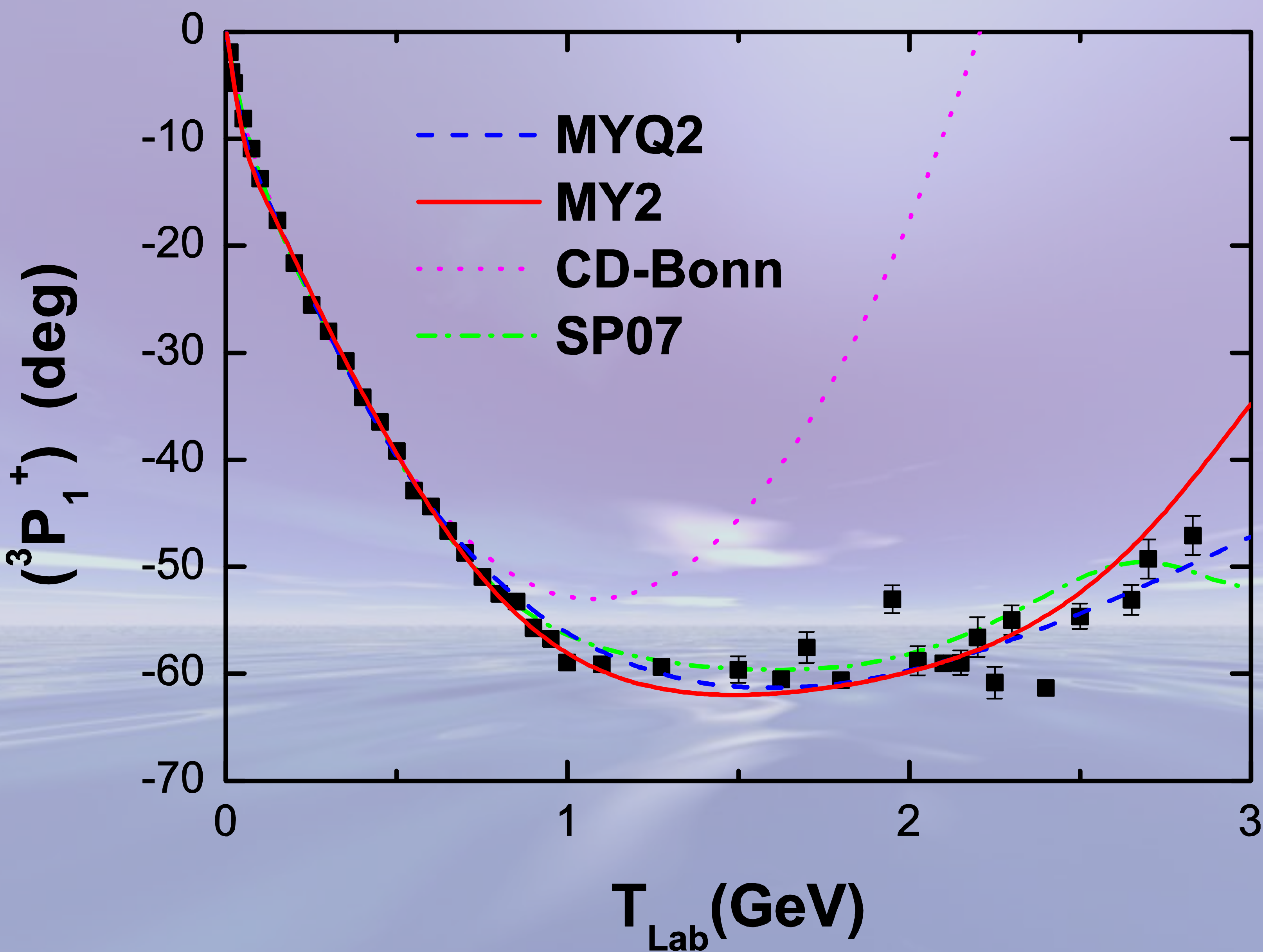
Experimental data:
O. Dumbrajs et al., Nucl Phys. B 216 (1983) 277

Experimental data: SAID (http://gwdac.phys.gwu.edu)
CD-Bonn: R. Machleidt, Phys. Rev. C 63 (2001) 024001
SP07: R.A. Arndt et al., Phys. Rev. C 76 (2007) 025209



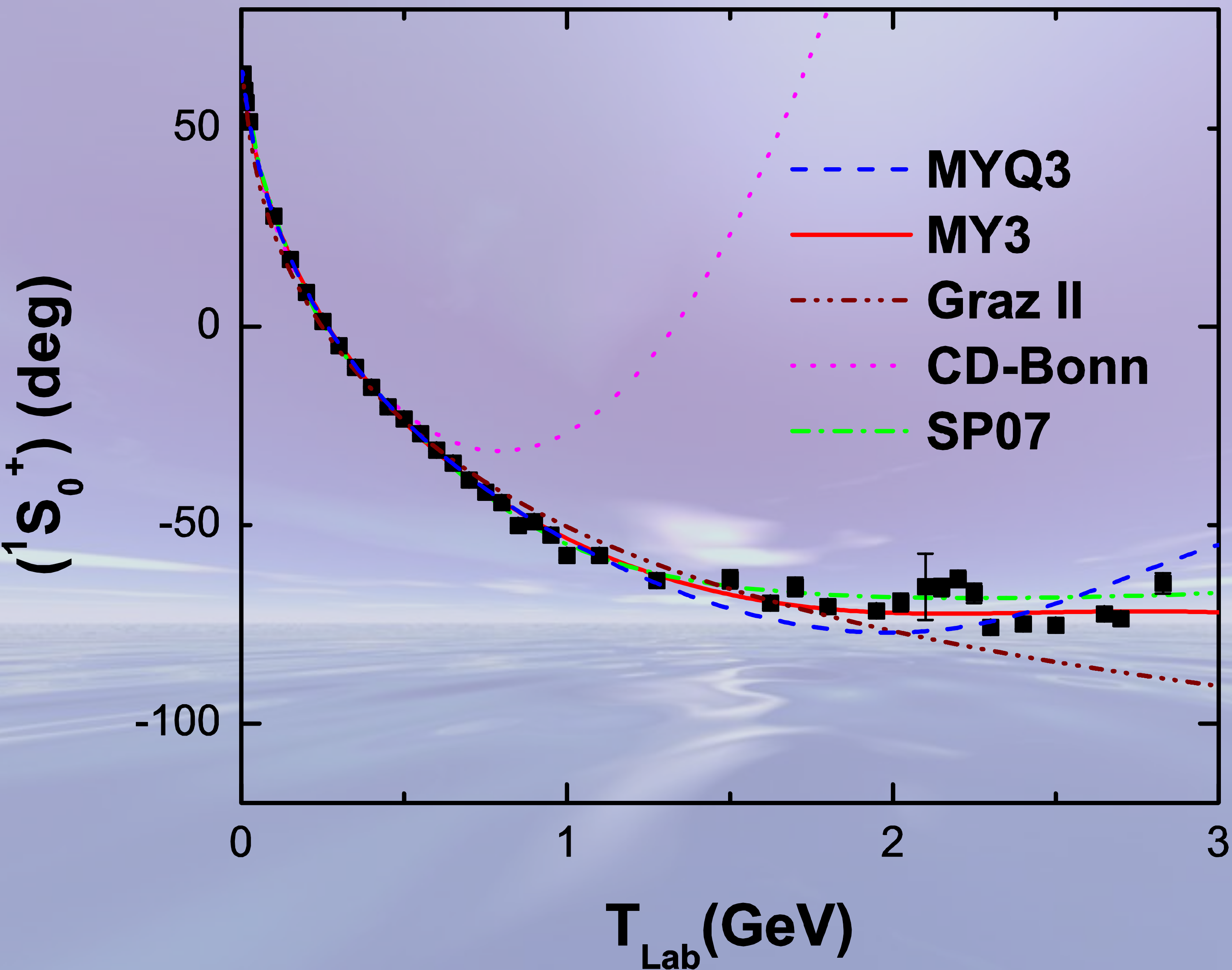


25
0
-25
-50
-75
-100
0
1
2
3
$(^3P_0^+)$ (deg)
T_{Lab}(GeV)
MYQ2
MY2
CD-Bonn
SP07



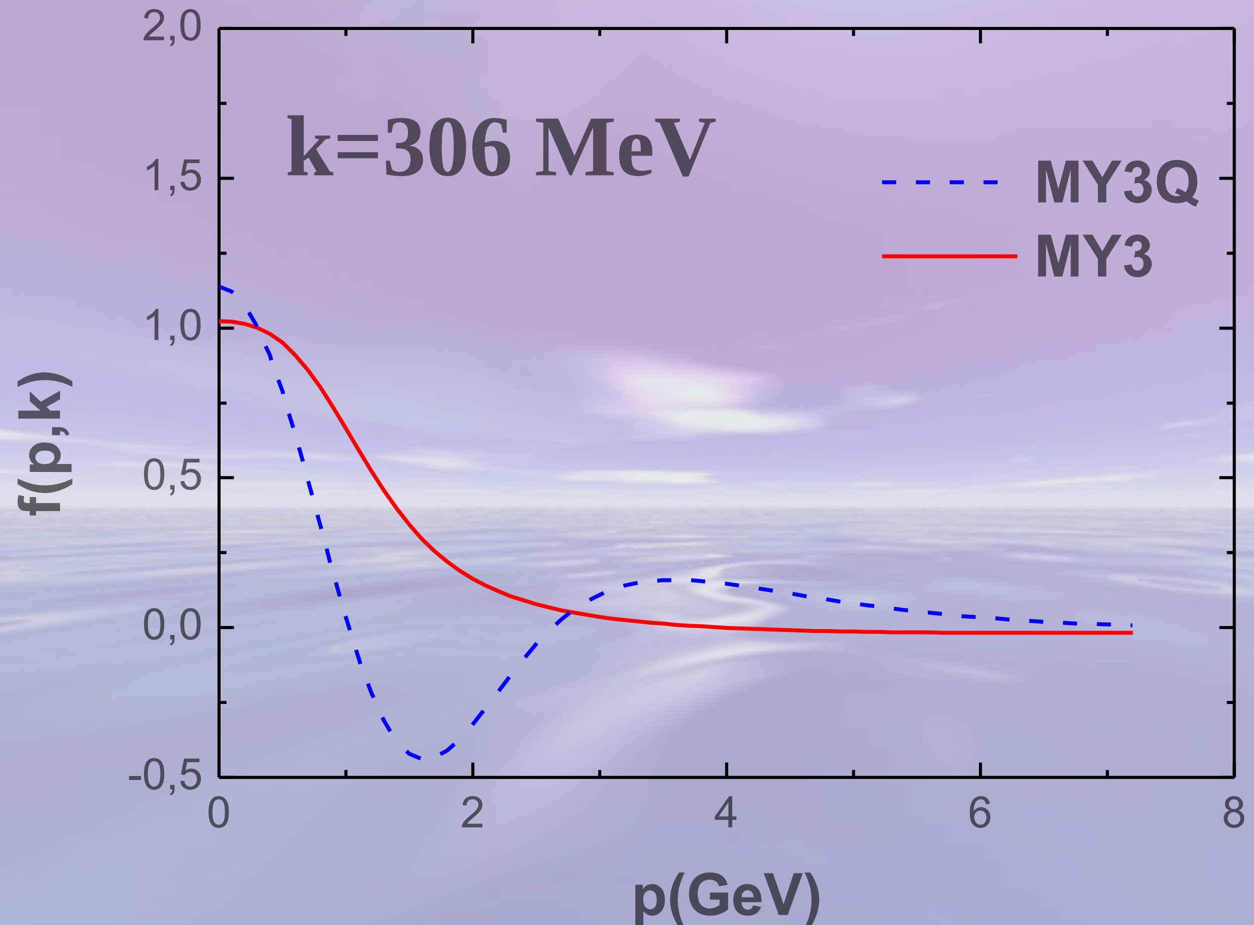
MYQ2
MY2
CD-Bonn
SP07
$(^3P_1^+)$ (deg)
0
-10
-20
-30
-40
-50
-60
-70
0
1
2
3
T_{Lab}(GeV)

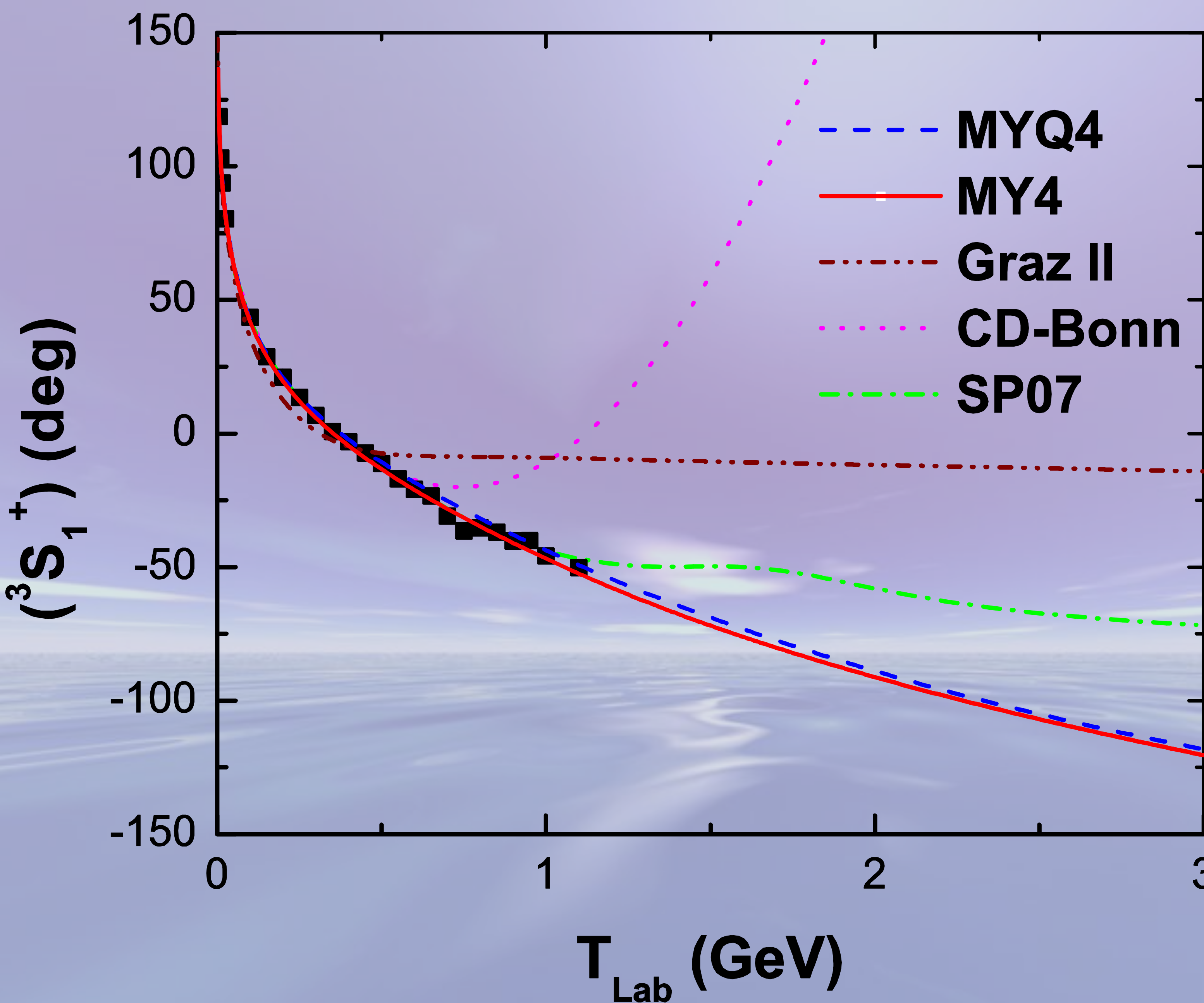
Graz II: L. Mathelitsch, W. Plessas, M. Schweiger, Phys. Rev. C 26 (1982) 65



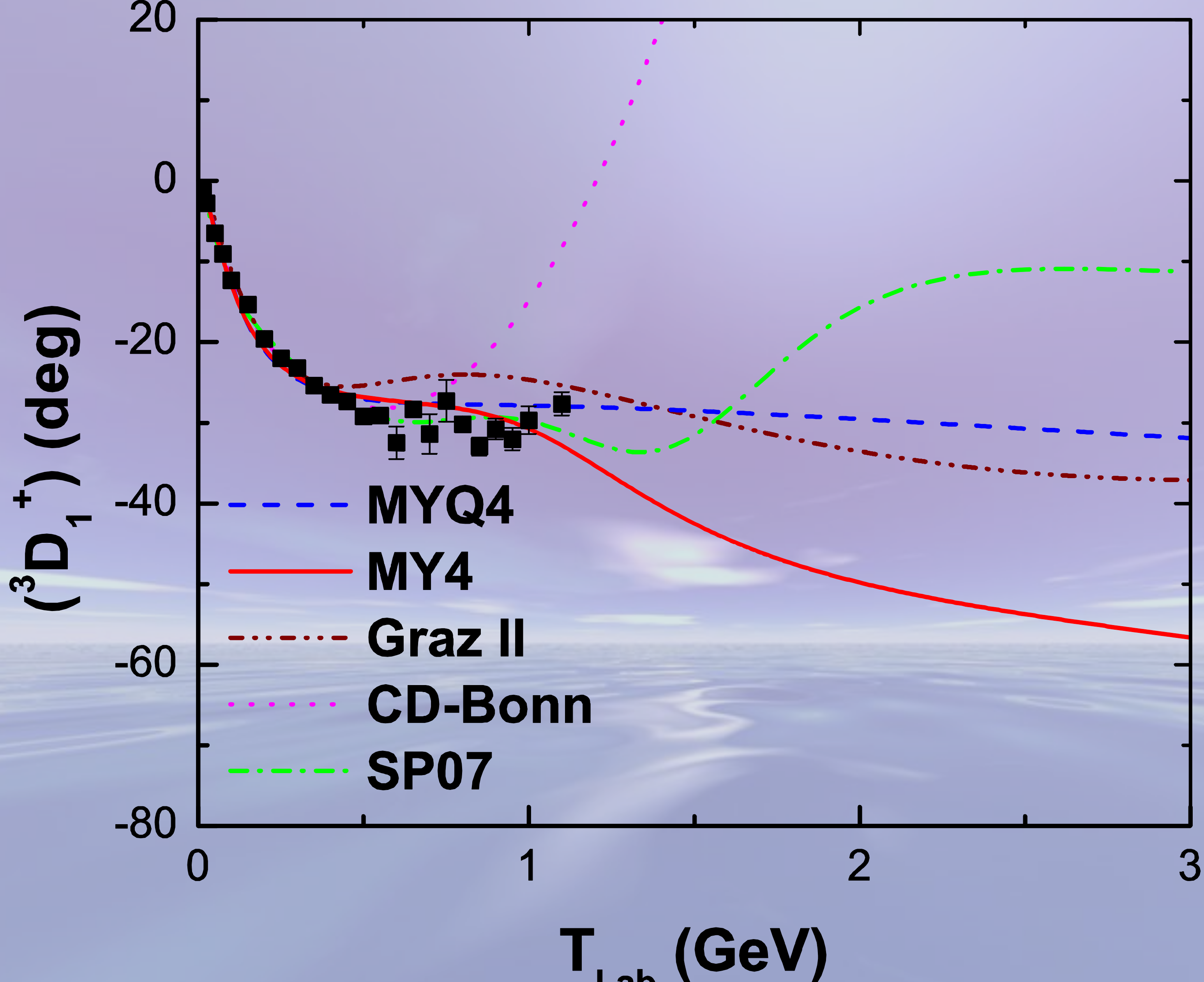
H.P. Noyes, Phys. Rev. Lett. 15 (1965) 538;
K.L. Kowalski, Phys. Rev. Lett. 15 (1965) 798

$$f(p,k)=\frac{t(p,k;s)}{t(k,k;s)}$$ **- Noyes-Kowalski half-off-shell function**

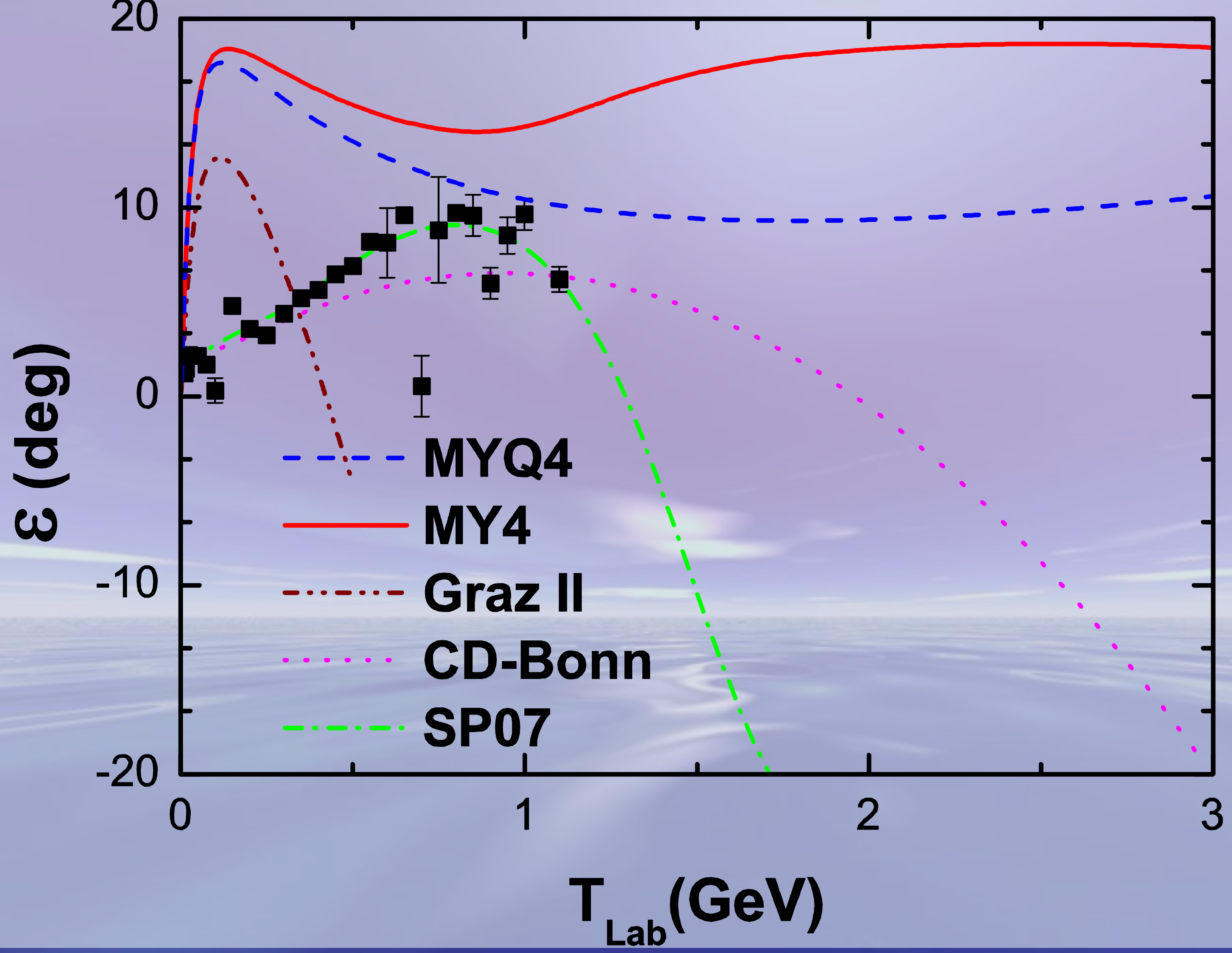




150
100
50
0
-50
-100
-150
0
1
2
3
$(^3S_1^+)$ (deg)
T_{Lab} (GeV)
MYQ4
MY4
Graz II
CD-Bonn
SP07



20
0
-20
-40
-60
-80
0
1
2
3
$(^3D_1^+)$ (deg)
T_{Lab} (GeV)
MYQ4
MY4
Graz II
CD-Bonn
SP07



20
10
0
-10
-20
0
1
2
3
ε (deg)
T_Lab (GeV)
MYQ4
MY4
Graz II
CD-Bonn
SP07

Deuteron electrodisintegration,

- **Limits of applicability of the separable kernel with standard (Yamaguchi-type) form factors are discussed**
- **New kernels of various ranks with form factors which have no poles on the real axis in p_0 complex plane are constructed for the description of partial states with J=0,1**
- **Within the model we manage to describe well low-energy parameters and phase shifts of the elastic np scattering up to ~ 3 GeV**

S.G. Bondarenko, V.V. Burov, W-Y. Pauchy Hwang, E.P. Rogochaya, JETP Lett. 87 (2008) 653-658 (arXiv:0804.3525).

S.G. Bondarenko, V.V. Burov, E.P. Rogochaya, Y. Yanev, Proceedings of 18th International Baldin Seminar on High Energy Physics Problems: ISHEPP 2006, v.2. Dubna, Russia,2008. P. 120-129 (arXiv:0806.4866).

S.G. Bondarenko, V.V. Burov, E.P. Rogochaya, W-Y. Pauchy Hwang, Nucl.Phys. A832:233-248, 2010 (arXiv:0810.4470 [nucl-th]).

S.G. Bondarenko, V.V. Burov, E.P. Rogochaya, W-Y. Pauchy Hwang, doi:10.1016/j.nuclphysa.2010.08.007 (arXiv:1002.0487 [nucl-th]).

Outlook (plans):

- **There is a model of the separable NN-interaction to investigate deuteron structure in elastic and inelastic (photo-, electrodisintigration) reactions in wide range of energies – first application, see report of E. Rogochaya**

- **With the constructed separable kernel it is possible to investigate the Final-State Interactions in the outgoing np-pair in the deuteron breakup reactions**

- **<u>Very interesting</u> to analyze the lepton-antilepton pair creation in the inelastic np-scattering (np->np *l* anti-*l*)**