Double Spin Correlations in the Reaction dd->pnpn and its Relation to the pn Correlations

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CONTENT

- Motivation :
  SPD NICA experiment at the first stage
- Dibaryons, multiquark configurations in interaction of hadrons,
  Color transparency, constituent counting rules
- Data on A_{NN} for pp->pp at $\vartheta_{cm} = 90^o, \sqrt{s} = 3 - 5$ GeV and theoretical models
- How to get A_{NN} pn->pn from dd->pnpn?
- Conclusion

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(NICA SPD workshop, October 5-6, 2020; https://indico.jinr.ru/event/1525/)

Possible Studies at the First Stage of the NICA Collider Operation with Polarized and Unpolarized Proton and Deuteron Beams

V. V. Abramov[a], A. Aleshko[b], V. A. Baskov[c], E. Boos[b], V. Bunichev[b], O. D. Dalkarov[c], R. El-Kholy[d], A. Galoyan[e], A. V. Guskov[f], V. T. Kim[g, h], E. Kokoulina[e, i], I. A. Koop[k, l, m], B. F. Kostenko[m], A. D. Kovalenko[e, †], V. P. Ladygin[e], A. B. Larionov[o, n], A. I. L'vov[c], A. I. Milstein[j, k], V. A. Nikitin[e], N. N. Nikolaev[p, z], A. S. Popov[j], V. V. Polyanskiy[c], J.-M. Richard[q], S. G. Salnikov[j], A. A. Shavrin[r], P. Yu. Shatunov[j, k], Yu. M. Shatunov[j, k], O. V. Selyugin[n], M. Strikman[s], E. Tomasi-Gustafsson[t], V. V. Uzhinsky[m], Yu. N. Uzikov[f, u, v, *], Qian Wang[w], Qiang Zhao[x, y], and A. V. Zelenov[g]

ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА
2021. Т. 52. ВЫП. 6. С. 1392–1529

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SEARCH FOR ONSET OF THE TRANSITION REGION

$$hadrons \to q, g$$

"One of the outstanding issues of strong interaction physics is understanding the dynamics of the transition between hadronic to quark-gluon phases of matter".

F. Gross, P. Klempt et al., 50 Years of QCD, e-print: 2212.11107[hep-ph];

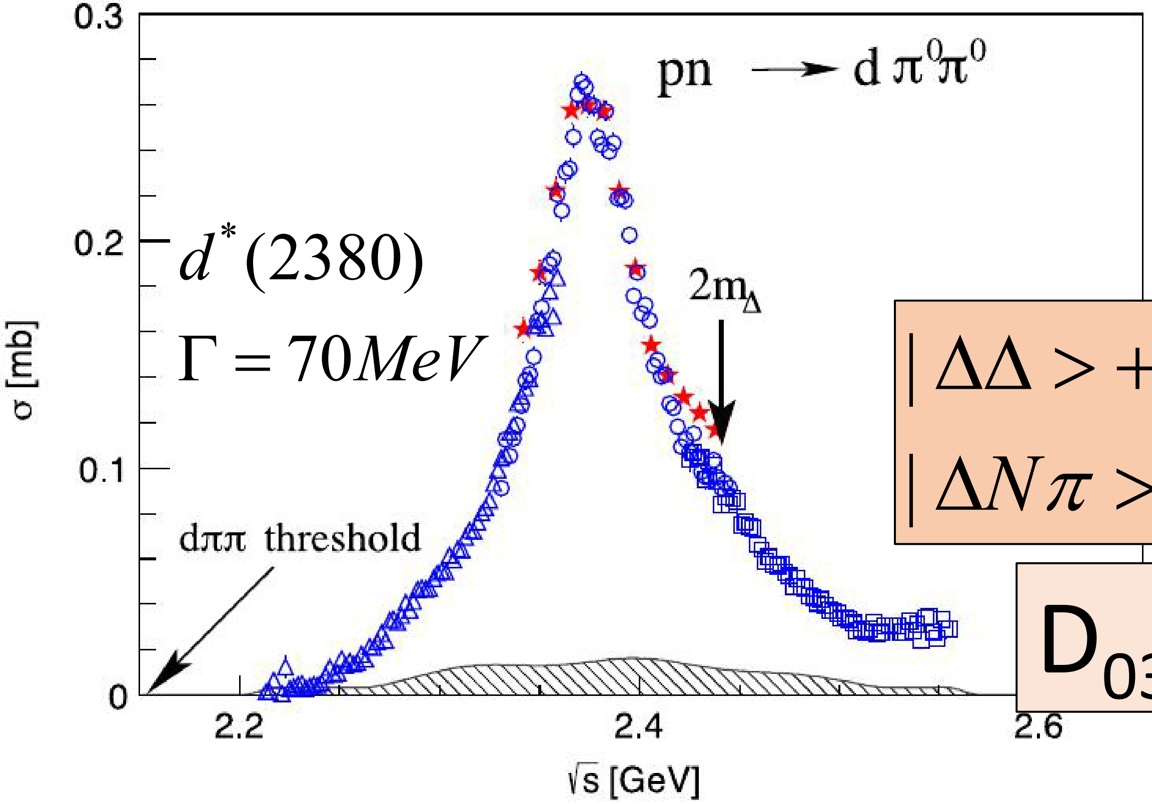
Three remarkable phenomena:
COLOR TRANSPARENCY A(p,2p)B
CONSTITUENT COUNTING RULES
MULTIQUARK CONFIGURATIONS
…

Double polarized pN-elastic scattering at 90°
includes all these features $3GeV \le \sqrt{s_{NN}} \le 5.5GeV$

1. DIBARYON RESONANCES

WASA@COSY

H. Clement / Progress in Particle and Nuclear Physics 93 (2017) 195–242

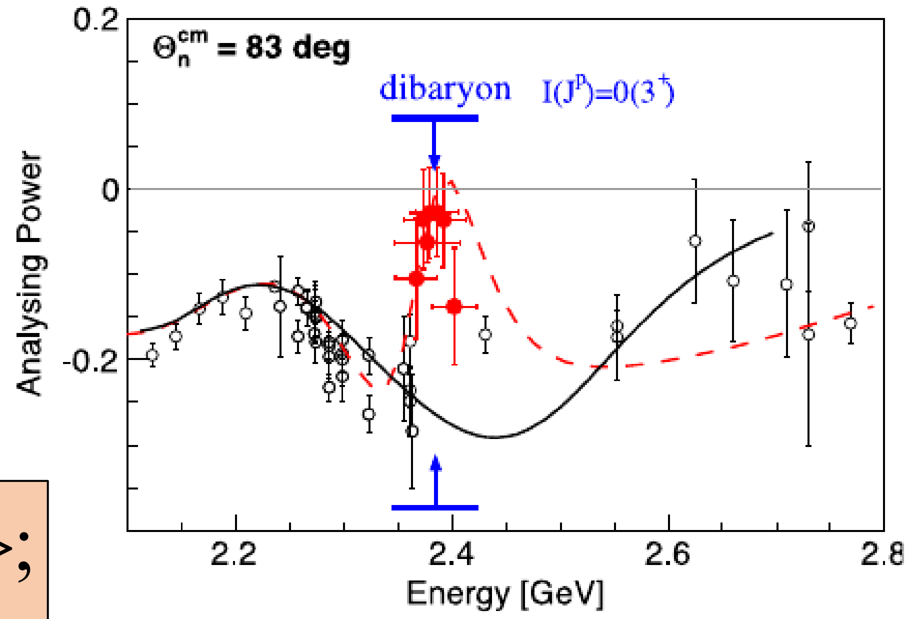


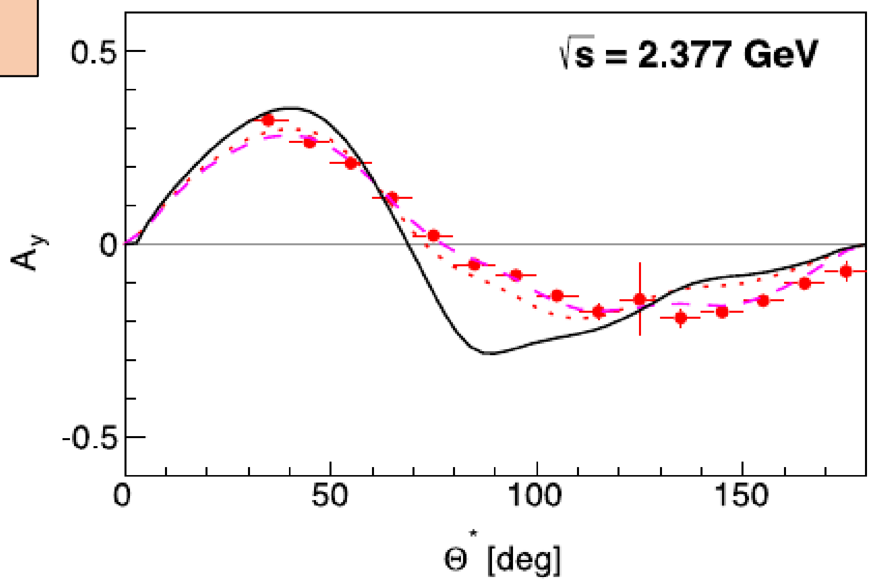
$| \Delta\Delta > + | C\bar{C} >;$

$| \Delta N \pi >$

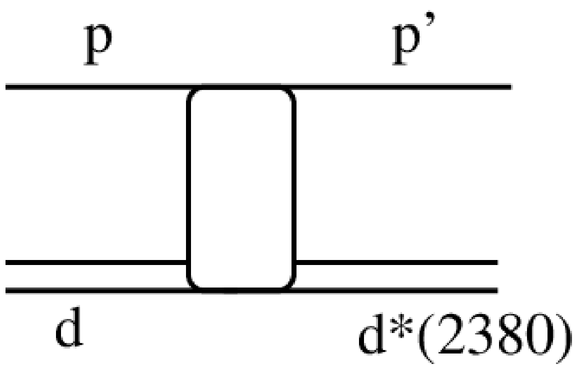
D_{03}

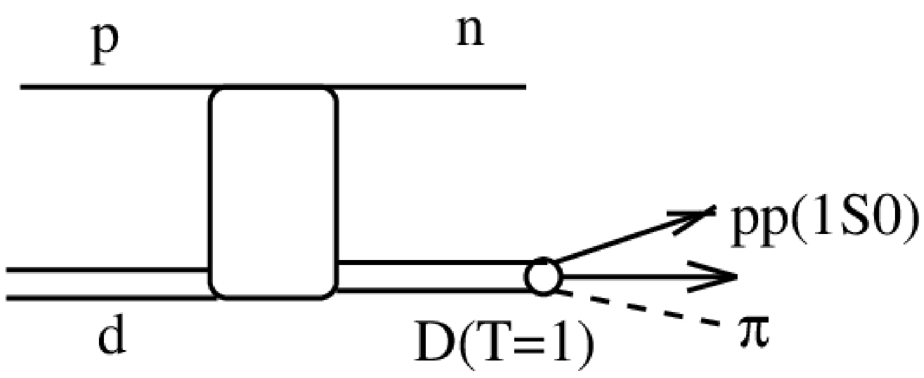
H. Clement / Progress in Particle and Nuclear Physics 93 (2017) 195–242



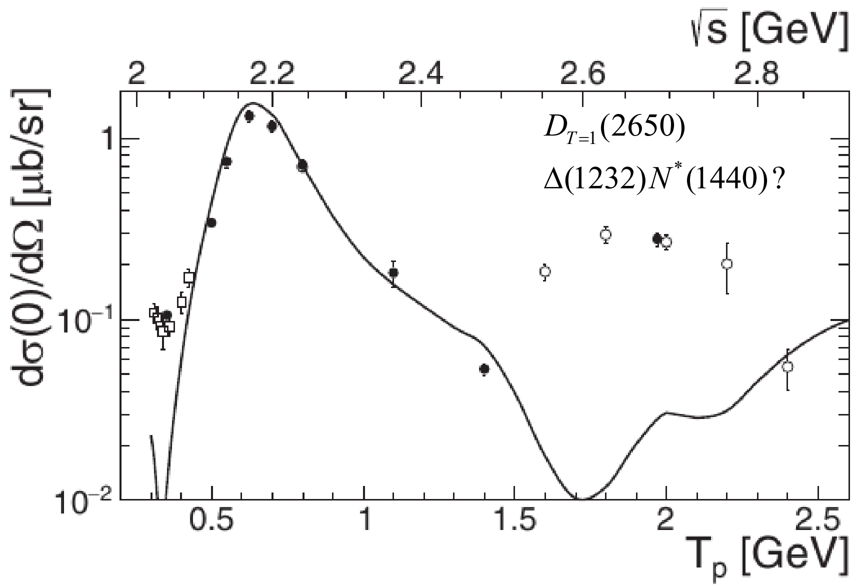


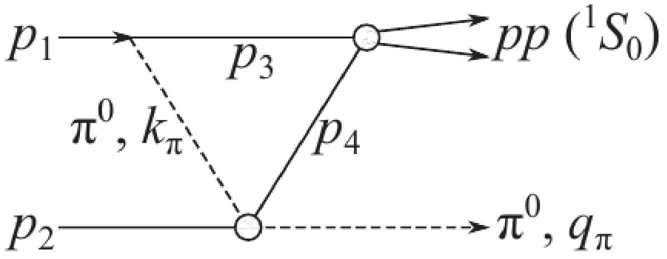
DIBARYONS IN pp and pd collisions





PHYSICAL REVIEW C **107**, 015202 (2023)





PHYSICAL REVIEW C **107**, 015202 (2023)

ANKE@COSY

Resonant behavior of the $pp \to \{pp\}_s\pi^0$ reaction at the energy $\sqrt{s} = 2.65$ GeV

D. Tsirkov,[1] B. Baimurzinova,[1,2,3,*] V. Komarov,[1] A. Kulikov,[1] A. Kunsafina,[1,2,3] V. Kurbatov,[1] Zh. Kurmanalyiev,[1,2,3] and Yu. Uzikov[1,4,5]

Tetraquarks, pentaquarks at LHCb … Octoquarks(?)

2.COLOR TRANSPARENCY

Color transparency (CT) is an unique prediction of QCD:
in the final (and/or initial) state interaction of hadrons with nuclear medium must vanish for exclusive processes at high momentum transfer (A. Mueller, S. Brodsky; 1982)

CT is necessary condition for factorization in exclusive hard processes

For latest review of CT see:

D. Dutta, K. Hafidi, M. Strikman, Prog. Part. Nucl. Phys. 69 (2013) 1;
50 Years of QCD (2022), G. Sterman, P. 5.10

CT is well established for meson production,
for baryons is questionable (see A.B. Larionov, PRC (2023) and references therein).

3. Constituent Counting Rules

Are large angle two body processes being point like probes?

Matveev, Muradyan, Tavkhelidzhe - **self silimarity**
Brodsky, Farrar - **pQCD**
Polchinski, Strassler - **AdS/CFT duality**

pQCD -large angle two body reactions ($-t/s$=const, $s \to \infty$) $\pi + p \to \pi + p$, $p + p \to p + p$,...

Dimensional quark counting rules:

$$\frac{d\sigma}{dt} = f(\theta_{c.m.}) s^{(-\sum n_{q_i} - \sum n_{q_f} + 2)}$$

number of constituents in initial state

number of constituents in final state

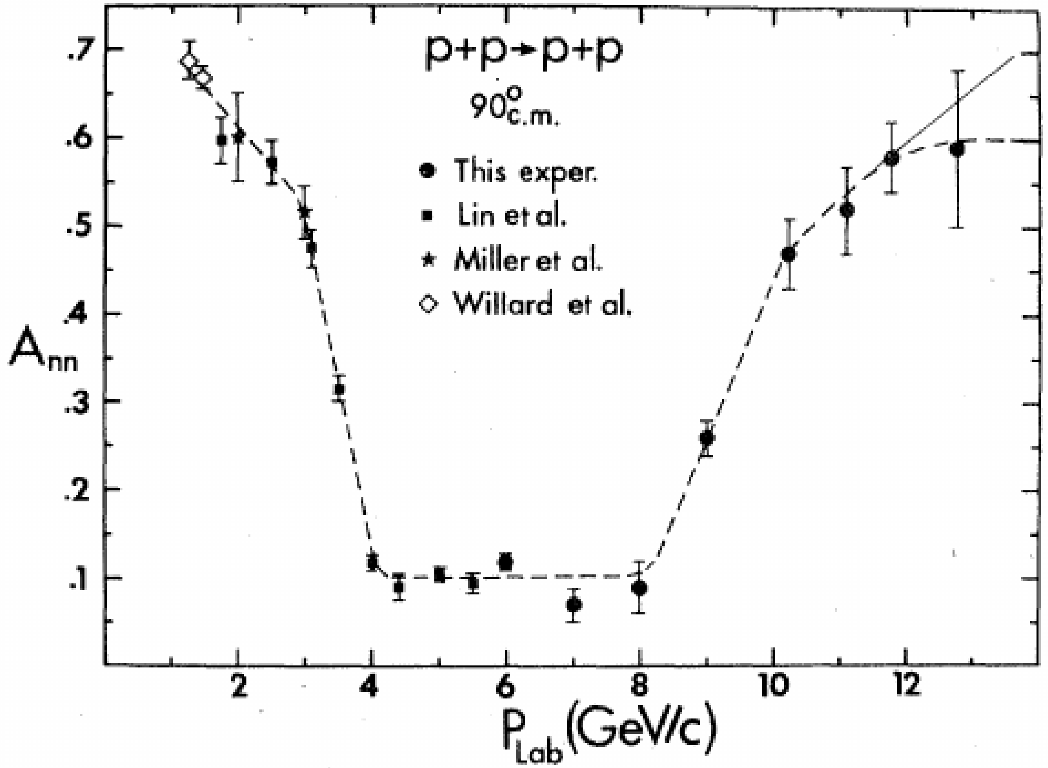
Indication to octoquark configurations in hard double polarized pp-> pp

SPIN-SPIN EFECTS IN HARD pp ELASTIC SCATTERING

PHYSICAL REVIEW D VOLUME 23, NUMBER 3 1 FEBRUARY 1981

Energy dependence of spin-spin effects in *p-p* elastic scattering at $90^{\circ}_{\text{c.m.}}$

E. A. Crosbie, L. G. Ratner, and P. F. Schultz
Argonne National Laboratory, Argonne, Illinois 60439



$$A_{NN} = \frac{d\sigma(\uparrow\uparrow) - d\sigma(\uparrow\downarrow)}{d\sigma(\uparrow\uparrow) + d\sigma(\uparrow\downarrow)}$$

$$\vartheta_{cm} = 90^{\circ}$$

pp(90°)-dynamics at very short distances:

$$\sqrt{s} = 5-7GeV, -t = 5-10GeV^2 : r_{NN} \sim 1/\sqrt{-t} \leq 0.1 fm$$

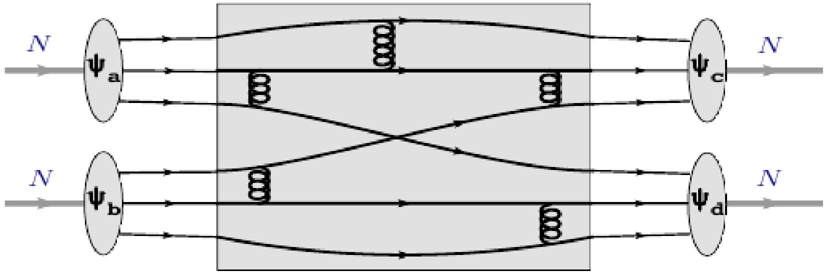
Three aspects of QCD dynamics in pp(90°)-elastic:

i) $d\sigma^{pp}(s, \vartheta_{cm} = 90^{\circ}) \sim s^{-10}$, but unexpected oscillations at s=10-20 GeV^2

ii) $A_{NN} = \frac{d\sigma(\uparrow\uparrow) - d\sigma(\uparrow\downarrow)}{d\sigma(\uparrow\uparrow) + d\sigma(\uparrow\downarrow)}$ experiment contradicts to **pQCD : A_{NN}^{pQCD}=1/3**

iii) Bump in color transparency in A(p,2p) at $4.9GeV \leq \sqrt{s_{NN}} \leq 5.5GeV$

S.Brodsky, de Teramond, PRL 60 (1988) 1924.
Possible explanation for all three observations:
assumes octoquarks at the thresholds $s\bar{s}\,,c\bar{c}$



$$\phi_1^{\rm PQCD}=2\phi_3^{\rm PQCD}=-2\phi_4^{\rm PQCD}=4\pi CF(t)F(u)[(t-m_d^2)/(u-m_d^2)+(u\leftrightarrow t)]e^{i\delta}.$$

$\phi_3 = M(+-,+-)$ $$\sigma A_{NN}=|\phi_3|^2;\sigma=3|\phi_3|^2;A_{NN}^{pQCD}=\frac{1}{3}$$

pQCD QIM

$$\phi_3^{\rm res}=12\pi\frac{\sqrt{s}}{p_{\rm c.m.}}d^1_{1,1}(\theta_{\rm c.m.})\frac{(1/2)\Gamma^{pp}(s)}{M^*-E_{\rm c.m.}-\frac{1}{2}i\Gamma},$$

Interference of pQCD term and non-perturbative resonance term allows one to explain all three above features

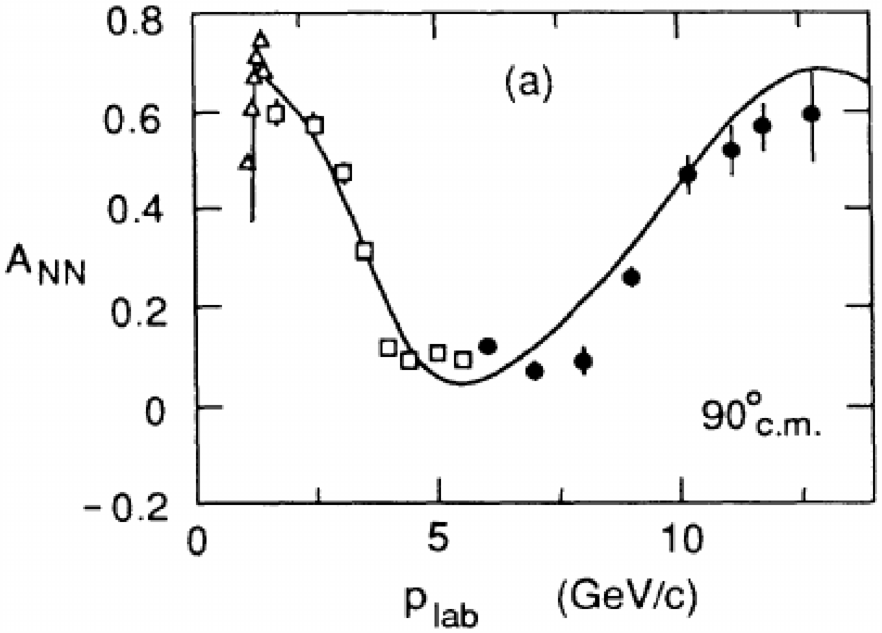
Octoquark resonances: $J=L=S=1$ $uuds\bar{s}uud$ $\sqrt{s}=3GeV$

$uudc\bar{c}uud$ $\sqrt{s}=5GeV$ $pp\to p[J/\psi\, p]$

Spin Correlations, QCD Color Transparency, and Heavy-Quark Thresholds in Proton-Proton Scattering

Stanley J. Brodsky and Guy F. de Teramond
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

(Received 14 January 1988)



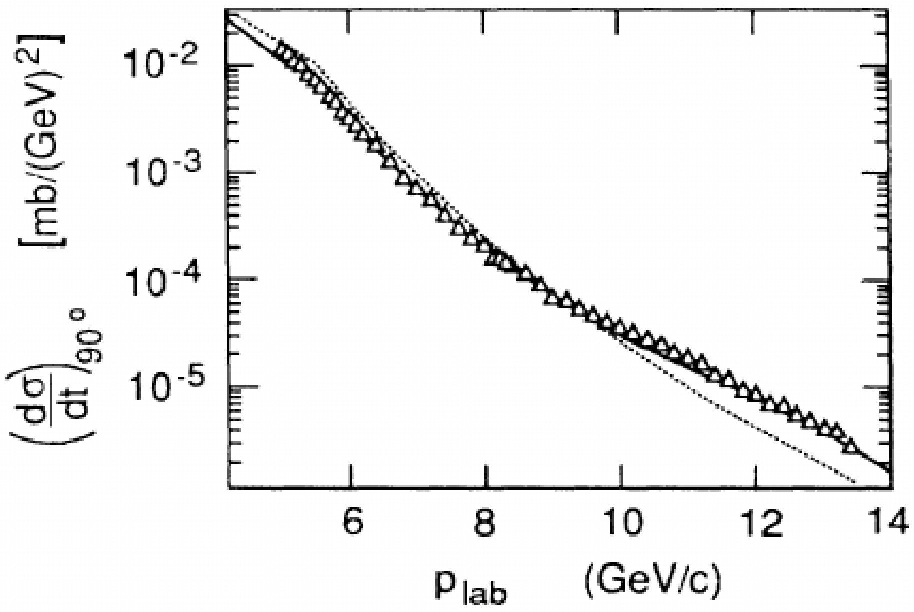
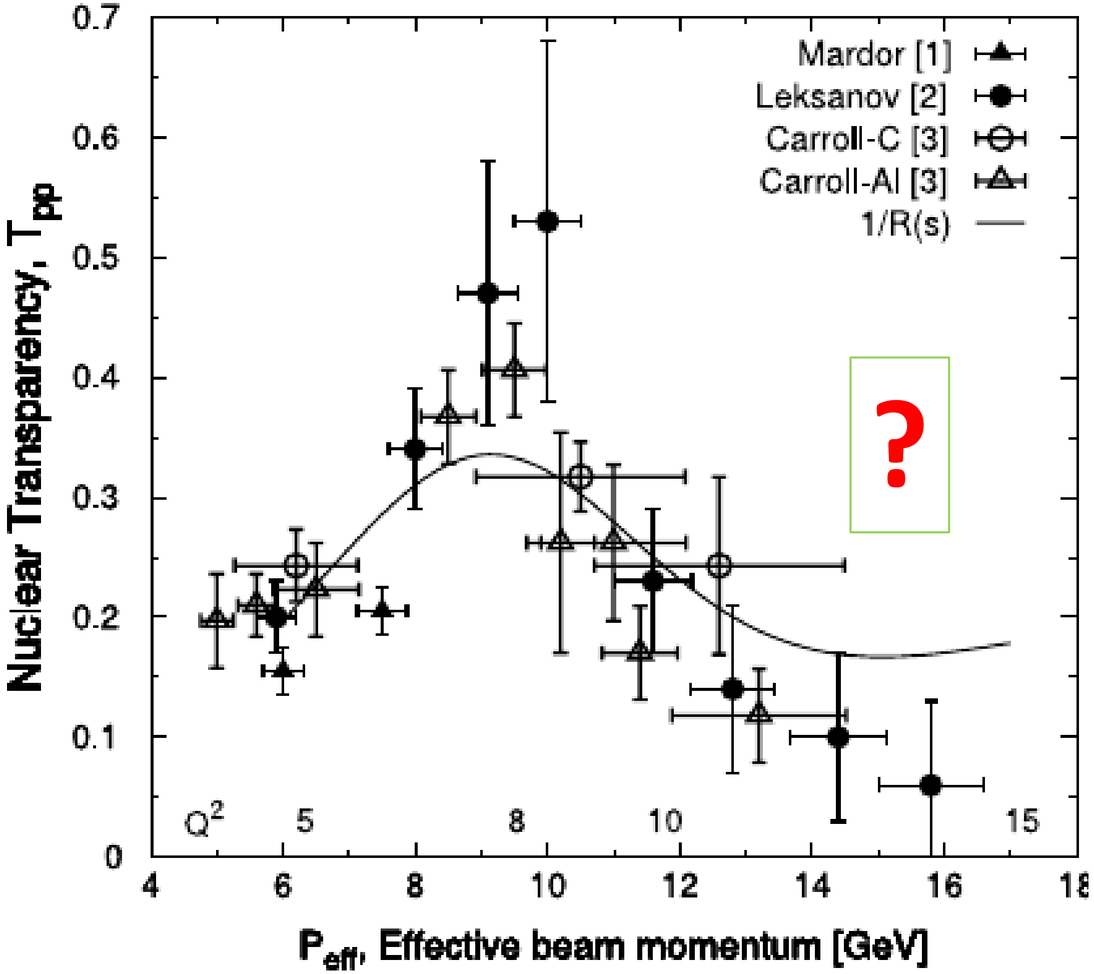


FIG. 1. Prediction (solid curve) for $d\sigma/dt$ compared with the data of Akerlof *et al.* (Ref. 16). The dotted line is the background PQCD prediction.

CT for baryons
A(p,2p)

PUZZLE

D. Dutta et al. / Progress in Particle and Nuclear Physics 69 (2013) 1–27



Unexpected drop of T in A(p,2p) at high P_L is not understood:

- J. Ralston, B.Pire, PRL 61 (1988) 1823

Nuclear filtering : $f_{pp} = f_{QC} + f_L$

f_{QC} - quark counting (PLC -size);

f_L - Ladshoff (normal size);

Attenuation for f_L in nuclear medium

- due to intermediate (very broad, $\Gamma \sim 1 GeV$) $6qc\bar{c}$ resonance formation at the charm threshold , S. Brodsky , G. F. de Teramond, PRL 60(1988) 1924

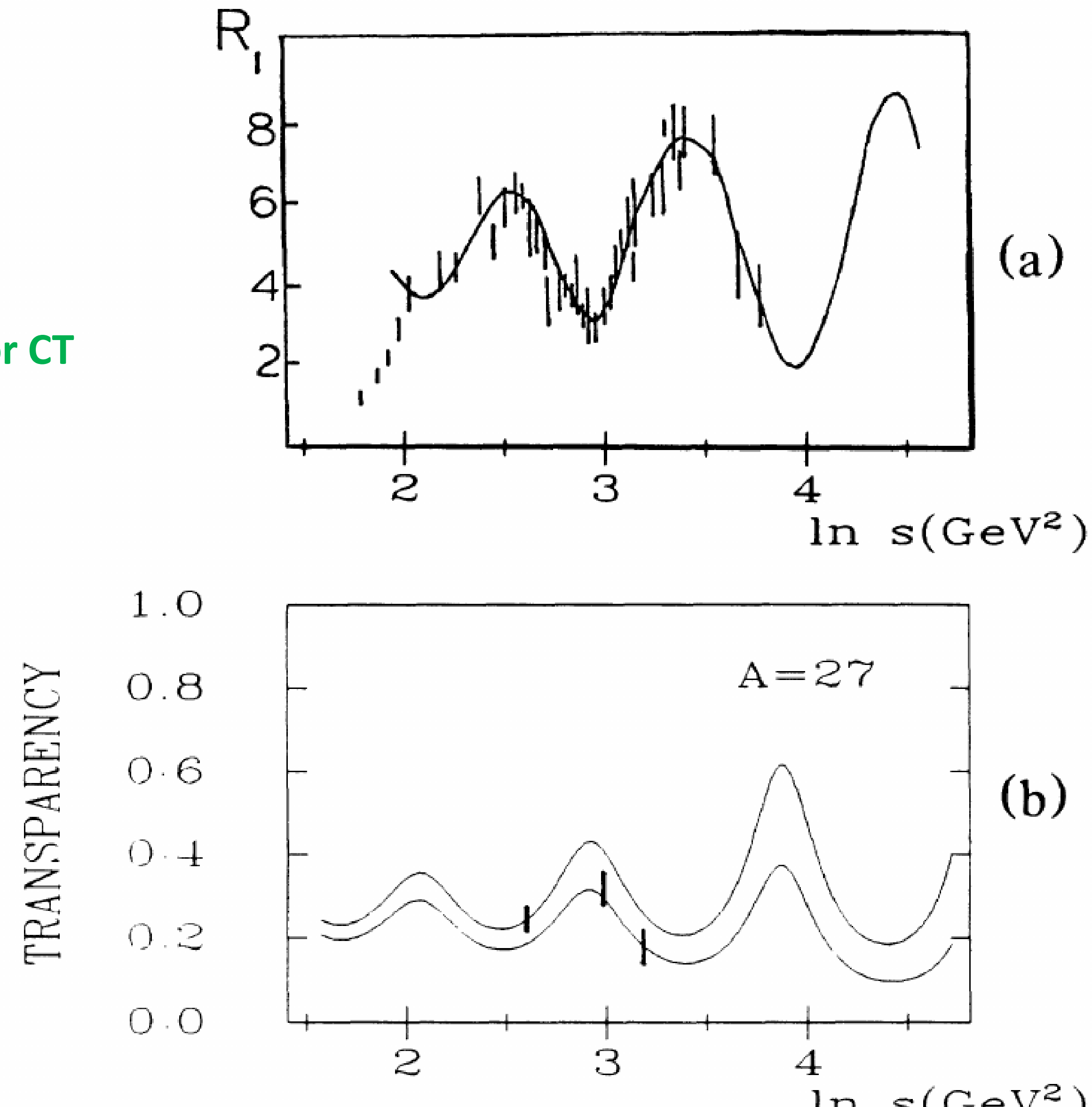
D. Bhetuwal et al. (Hall C), PRL 126 (2021) : CT is excluded in $^{12}C(e,e'p)$ for Q^2 up to 14 GeV^2

Another explanation of pp-oscillations in d\sigma/dt at 90º and CT bump: (but not for A_{NN})

J.P. Ralston, B. Pire.
PRL 61 (1988) 1823;
PRL 49 (1982) 1605

Nuclear filtering mechanism for CT

$$T = \frac{d\sigma^{pA}/dt}{A d\sigma^{pp}/dt}$$



$$R_1 = s^{10}\frac{d\sigma^{pp}}{dt}$$

J.P. Ralston, B. Pire, PRL 61 (1988) 1823

A. Carroll et al. PRL 61(1988) 1698 ; A(p,2p)

The unexpected energy dependence of high-energy fixed-angle *pp* elastic scattering in a nuclear target can be interpreted in terms of interference between two perturbative QCD subprocesses. By proposing the attenuation of Landshoff-type contributions in nuclei, we obtain a parameter-free relation that matches the energy dependence of the data of Carroll *et al.* The approximations improve with larger *A* and higher energy, leading to a prediction of oscillatory energy dependence for the transparency ratio at higher energy.

$$R_1(s) = s^{10}\frac{d\sigma}{dt}(pp)\,|_{90^\circ} \propto 1 + \rho_1 (s/1\ \mathrm{GeV}^2)^{1-K}\cos[\phi(s)+\delta_1] + \rho_1^2 (s/1\ \mathrm{GeV}^2)^{2-2K}/4\,.$$

$$\phi(s) = \frac{\pi}{0.06}\ln\ln(s/\Lambda_{\mathrm{QCD}}^2)$$

The constant ρ_1, measuring the relative normalization of M_L to M_{QC}, equals 0.08 from a fit to the region 10 $\mathrm{GeV}^2 \lesssim s \lesssim 40\ \mathrm{GeV}^2$ [Fig. 1(a)]. This is large enough to lead to oscillations of more than a factor of 2 in the

For future:

i) s-dependence at $\vartheta_{cm} = 60^\circ$

Ii) $\pi p \to \pi p$

About phenomenology of pN- elastic scattering at $\sqrt{s_{NN}}$ = 3-6 GeV

W.P. Ford, J.W. van Orden, PRC 87 (2013) 014004, "Regge-model for nucleon-nucleon spin-dependent amplitudes", s= 6 GeV^2

pp-Regge, see also: A.Sibirtsev et al. EPJ A(2010)
P_L=3 - 50 GeV/c
-t< $2(GeV/c)^2$

No model predictions in hard pN- region

Similar data on A_{NN} in pn-pn elastic scattering will be very valuable due to different spin-isospin dependence of p-n (T=0) as compared to p-p.

This can be done at NICA SPD.

How to get a double – spin correlations in pn->pn from dd->pnpn?

Double spin correlations in pn->pn

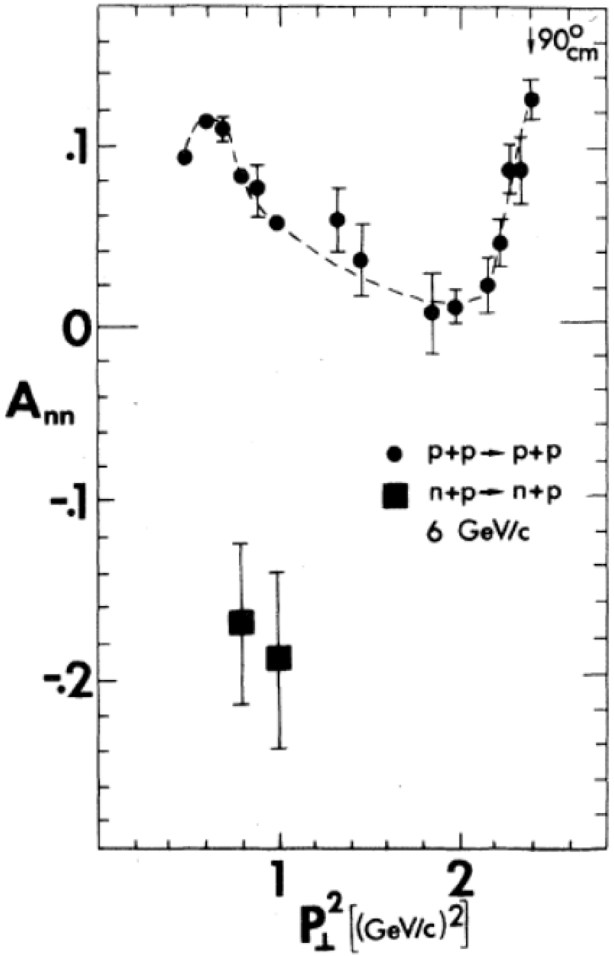


FIG. 2. The spin-spin correlation parameter, A_{nn}, for pure-initial-spin-state nucleon-nucleon elastic scattering at 6 GeV/c is plotted against the square of the transverse momentum. The proton-proton and neutron-proton data are quite different.

14 PHYSICAL REVIEW LETTERS 1 October 1979

pin-Spin Forces in 6-GeV/c Neutron-Proton Elastic Scattering

. Crabb, P. H. Hansen, A. D. Krisch, T. Shima, and K. M. Terwilliger
l Laboratory of Physics, The University of Michigan, Ann Arbor, Michigan 48109

$$(d\sigma/dt)_{\uparrow\uparrow} = \langle d\sigma/dt\rangle(1 + 2A + A_{nn}),$$

$$(d\sigma/dt)_{\downarrow\downarrow} = \langle d\sigma/dt\rangle(1 - 2A + A_{nn}),$$

$$(d\sigma/dt)_{\uparrow\downarrow} = (d\sigma/dt)_{\downarrow\uparrow} = \langle d\sigma/dt\rangle(1 - A_{nn}).$$

A -> 0

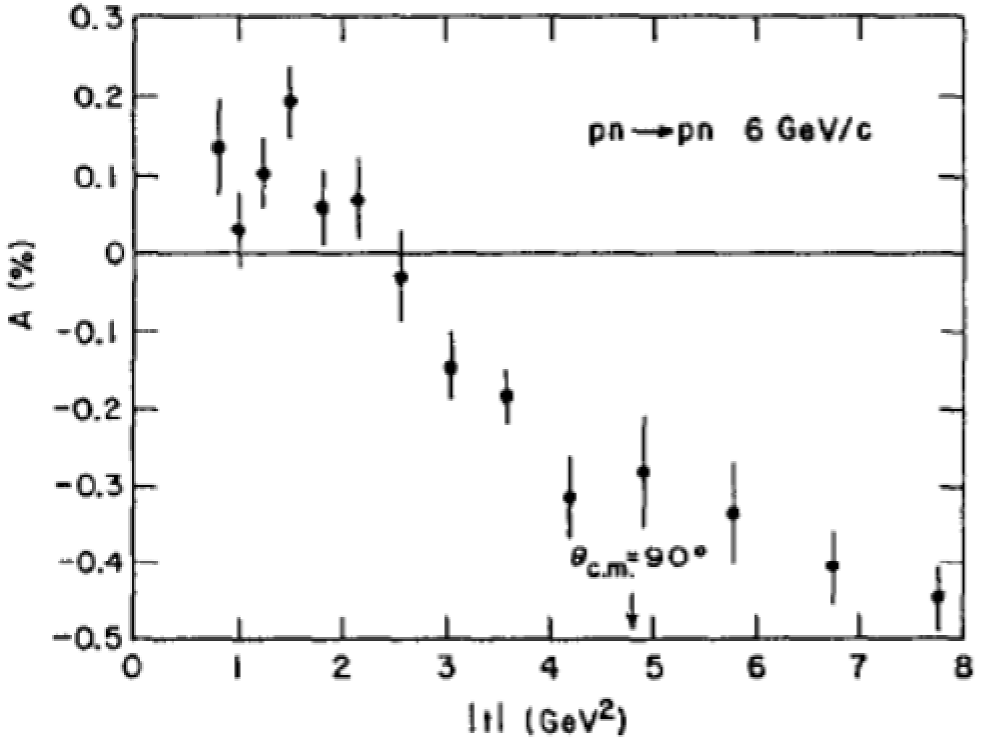
$$\frac{(d\sigma/dt)_{\uparrow\uparrow}}{(d\sigma/dt)_{\uparrow\downarrow}} \equiv \frac{(d\sigma/dt)_{\uparrow\uparrow} + (d\sigma/dt)_{\downarrow\downarrow}}{(d\sigma/dt)_{\uparrow\downarrow} + (d\sigma/dt)_{\downarrow\uparrow}} = \frac{1 + A_{nn}}{1 - A_{nn}}.$$

Nuclear Physics B279 (1987) 97 - 118
North-Holland, Amsterdam

SPIN EFFECTS IN HADRONIC REACTIONS

J. SOFFER

Fig. 1 - The analyzing power A for np elastic scattering at 6 GeV/c (taken from Ref. 5)



Unfortunately the energy is too low to draw definite conclusions on the nature of this effect and hopefully it will be remeasured at higher energies with the polarized proton beam on a deuterium target at BNL.

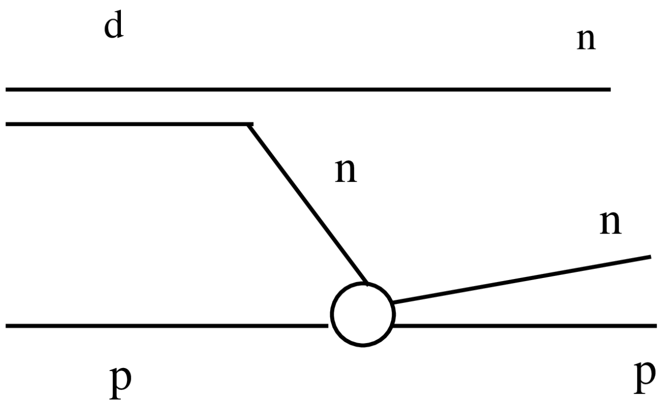
VOLUME 43, NUMBER 14 PHYSICAL REVIEW LETTERS 1 OCTOBER 1979

Spin-Spin Forces in 6-GeV/c Neutron-Proton Elastic Scattering

D. G. Crabb, P. H. Hansen, A. D. Krisch, T. Shima, and K. M. Terwilliger
Randall Laboratory of Physics, The University of Michigan, Ann Arbor, Michigan 48109

$$d^{\uparrow} p^{\uparrow} \longrightarrow pnp$$

Measurement was made of $d\sigma/dt$ for $n_\uparrow + p_\uparrow \to n + p$ at $P_\perp^2 = 0.8$ and 1.0 (GeV/c)^2 at 6 GeV/c. The 6-GeV/c 53%-polarized neutrons from the 12-GeV/c polarized deuteron beam at the Argonne zero-gradient synchroton were scattered from our 75%-polarized proton target. Both spins were oriented perpendicular to the scattering plane. We found large unexpected spin-spin effects in n-p elastic scattering which are quite different from the p-p spin-spin effects.

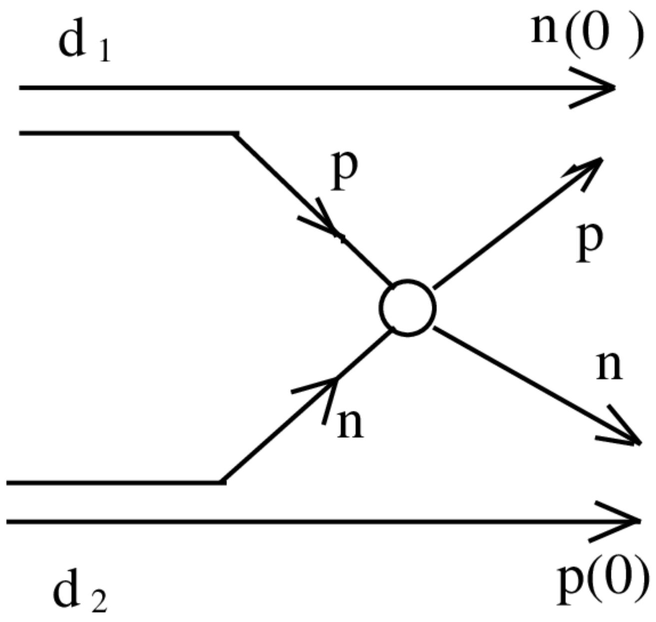


onance by a factor of 12.5. By carefully tuning the pulsed quadrupoles, the ZGS staff was able to jump this $0 - \nu_y$ resonance and obtain a beam of 12-GeV/c deuterons with a neutron polarization of $P_B = (53 \pm 3)\%$.

Measuring the polarization of these neutrons was also a new problem. A fast "uncalibrated"

Polarization: 53% for n, 75% for p

At SPD NICA $d^{\uparrow} d^{\uparrow} \to p(90^\circ) + n(90^\circ) + p_s(0) + n_s(0)$



Transversally polarized deuterons. Hard pn elastic scattering at 90°. Nucleons p (0) and n(0) are spectators.
The S-wave dominates in the deuterons at $\vec{q}_1 = \vec{q}_2 = 0$

S-waves :

$$\vec{p}_s = \vec{d}_1 / 2; \vec{n}_s = \vec{d}_d / 2 \qquad (1)$$

$$A^{dd}_{\vec{N}\vec{N}} \Rightarrow A^{pn}_{\vec{N}\vec{N}}(\theta^{pn}_{cm} = 90^\circ) \qquad (2)$$

(for any OZ)

S+D-waves: $\vec{q}_1 \neq 0 \uparrow\uparrow OZ, \vec{q}_2 \neq 0 \uparrow\downarrow OZ$ **OZ || beam**

$$A^{dd}_{Z,Z} \Rightarrow A^{NN}_{Z,Z} = \frac{\sigma_{\nearrow\nearrow} - \sigma_{\nearrow\swarrow}}{\sigma_{\nearrow\nearrow} + \sigma_{\nearrow\swarrow}} \qquad (3)$$

ISI@FSI and deviation from the conditions of Eq. (1) are under estimation

PHYSICAL REVIEW C **82**, 014003 (2010)

Vector and tensor analyzing powers in deuteron-proton breakup at 130 MeV

E. Stephan,[1,*] St. Kistryn,[2] R. Sworst,[2] A. Biegun,[1] K. Bodek,[2] I. Ciepał,[2] A. Deltuva,[3] E. Epelbaum,[4] A. C. Fonseca,[5] J. Golak,[2] N. Kalantar-Nayestanaki,[6] H. Kamada,[7] M. Kiš,[6] B. Kłos,[1] A. Kozela,[8] M. Mahjour-Shafiei,[6,†] A. Micherdzińska,[1,‡] A. Nogga,[9] R. Skibiński,[2] H. Witała,[2] A. Wrońska,[2] J. Zejma,[2] and W. Zipper[1]

TABLE I. Set of the polarization states used in the $^{1}\mathrm{H}(\vec{d},pp)n$ breakup experiment. The maximum polarizations P_Z, P_{ZZ} (for 100% efficiency of transitions in the ion source) and corresponding combinations of the magnetic fields are shown. The x indicates that the magnetic field is switched on, whereas the—indicates that the magnetic field is switched off. I_f denotes the full beam intensity. In the case of transitions with medium field on, the beam intensity is reduced to 2/3 of I_f in the case of 100% efficient transitions.

Polarization states		Magnetic fields				Beam intensity
P_Z	P_{ZZ}	SF1	SF2	MF	WF	
0	0	–	–	–	–	I_f
$+\frac{1}{3}$	+1	x	–	–	–	I_f
$+\frac{1}{3}$	−1	–	x	–	–	I_f
0	+1	x	–	x	–	$\frac{2}{3}I_f$
0	−2	–	x	x	–	$\frac{2}{3}I_f$
$+\frac{2}{3}$	0	x	x	–	–	I_f
$-\frac{2}{3}$	0	–	–	–	x	I_f

P_{yy}=0 for P_y=+2/3, -2/3

Comment by N.M. Piskunov

In this case measurement of A_{yy} in dd->pnpn seems to be similar to that for pp->pp (See Crabb et al. PRL 1978)

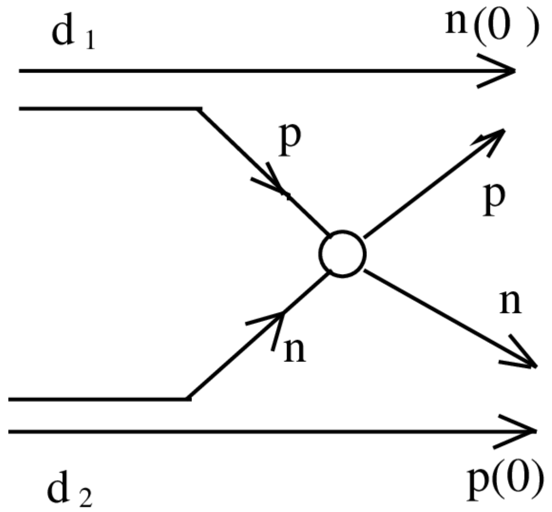
Elements of Formalism for dd->pnpn

$$M_{fi} = \sum_{\sigma'_2\sigma'_3} \frac{M(d_1 \to 12')iT_{NN}(2'3' \to 23)iM(d_2 \to 3'4)}{(p^2_{2'} - m^2_N + i\epsilon)(p^2_{3'} - m^2_N + i\epsilon)}$$

$$M(d_1 \to 12') = -(\varepsilon + q_1^2/m) < \chi_1\chi_2|\phi_\lambda > \sqrt{2m_p 2m_n 2m_d}$$
$$= -(\varepsilon + q_1^2/m)u(q_1)\frac{1}{\sqrt{4\pi}}(\frac{1}{2}\sigma_1\frac{1}{2}\sigma_{2'}|1\lambda_1)\sqrt{2m_p 2m_n 2m_d}$$

$$M_{fi} = \sum_{\sigma'_2\sigma'_3} 2m_d < \chi_1\chi'_2|\phi_{\lambda_1} >< \chi'_3\chi_4|\phi_{\lambda_2} > T_{NN}(2'3' \to 23)$$

$A^{d,d}_{y,y}$ CORRELATION FOR $d^{\uparrow}d^{\uparrow} \to pnpn$



$$M^{\sigma_1\sigma_2\sigma_3\sigma_4}_{\lambda_1\lambda_2}(dd \to pnpn) = \sum_{\sigma_p\sigma_n} < \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{\sigma_p}(p)\chi_{\sigma_n}(n) >$$

$$\times < \chi_{\sigma_1}(1), \chi_{\sigma_p}(p)|\phi_{\lambda_1}(d_1) >< \chi_{\sigma_4}(4), \chi_{\sigma_n}(n)|\phi_{\lambda_2}(d_2) >$$

$$< \chi_{\sigma_1}(1), \chi_{\sigma_p}(p)|\phi_{\lambda_1}(d_1) >= u(q_1)(\frac{1}{2}\sigma_1\frac{1}{2}\sigma_p|1\lambda_1),$$

$$< \chi_{\sigma_4}(4), \chi_{\sigma_n}(n)|\phi_{\lambda_2}(d_2) >= u(q_2)(\frac{1}{2}\sigma_1\frac{1}{2}\sigma_n|1\lambda_2),$$

$$d\sigma_{\lambda_1\lambda_2} = \frac{1}{9}\sum_{\sigma_1\sigma_2\sigma_3\sigma_4} M^{\sigma_1\sigma_2\sigma_3\sigma_4}_{\lambda_1\lambda_2}(dd \to pnpn)(M^{\sigma_1\sigma_2\sigma_3\sigma_4}_{\lambda_1\lambda_2}(dd \to pnpn))^* =$$

$$= \frac{1}{9}\sum_{\sigma_1\sigma_2\sigma_3\sigma_4} | < \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{\sigma_p=\lambda_1-\sigma_1}(p)\chi_{\sigma_n=\lambda_2-\sigma_4}(n) > |^2$$

$$\times(\frac{1}{2}\sigma_1\frac{1}{2}\lambda_1 - \sigma_1|1\lambda_1)^2(\frac{1}{2}\sigma_4\frac{1}{2}\lambda_2 - \sigma_4|1\lambda_2)^2 u(q_1)^2 u(q_2)^2.$$

$\lambda_1 = +1, \lambda_2 = \pm 1$

$$d\sigma_{\lambda_1=+1\lambda_2=+1} = \sum_{\sigma_2\sigma_3} u(q_1)^2 u(q_2)^2 | < \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{\sigma_p=+\frac{1}{2}}(p)\chi_{\sigma_n=+\frac{1}{2}}(n) > |^2$$

$$d\sigma_{\lambda_1=+1\lambda_2=-1} = \sum_{\sigma_2\sigma_3} u(q_1)^2 u(q_2)^2 | < \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{\sigma_p=+\frac{1}{2}}(p)\chi_{\sigma_n=-\frac{1}{2}}(n) > |^2$$

$A_{y,y}^{d,d}$ CORRELATION FOR $d^{\uparrow}d^{\uparrow} \to pnpn$

$$A_{y,y}^{dd} = \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \frac{d\sigma_{\lambda_1=+1\lambda_2=+1} - d\sigma_{\lambda_1=+1\lambda_2=-1}}{d\sigma_{\lambda_1=+1\lambda_2=+1} + d\sigma_{\lambda_1=+1\lambda_2=-1}}$$

$$A_{y,y}^{dd\to pnpn} = A_{y,y}^{pn\to pn}$$

$$A_{z,z}^{dd} = A_{z,z}^{pn}$$

But what about $\lambda = 0$ **?**

What about $\lambda = 0$?

Polarization of the beam

Unpolarized deuteron beam

$$P_Y = \frac{\mathcal{N}_{m=+1} - \mathcal{N}_{m=-1}}{\mathcal{N}_{m=+1} + \mathcal{N}_{m=-1} + \mathcal{N}_{m=0}},$$

$$P_{YY} = \frac{\mathcal{N}_{m=+1} + \mathcal{N}_{m=-1} - 2\mathcal{N}_{m=0}}{\mathcal{N}_{m=+1} + \mathcal{N}_{m=-1} + \mathcal{N}_{m=0}}$$

$$N_+ = N_- = N_0 \equiv n$$

$m = +1$	$m = -1$	$m = 0$
$N_+=2n$	0	$n \Rightarrow P_Y = \frac{2}{3}, P_{YY} = 0$
0	$N_-=2n$	$n \Rightarrow P_Y = -\frac{2}{3}, P_{YY} = 0$

Two sets of deuterons beams:

$$P_1 = +\frac{2}{3}, P_2 = +\frac{2}{3}$$

$$P_1 = +\frac{2}{3}, P_2 = -\frac{2}{3}$$

N_1

N_2

$$A_{YY}^{dd} = \frac{\mathcal{N}_1 - \mathcal{N}_2}{\mathcal{N}_1 + \mathcal{N}_2}$$

In terms of $d\sigma_{\lambda_1\lambda_2}$

$$A_{YY}^{dd} = \frac{2\cdot 2d\sigma_{++} + 2d\sigma_{+0} + 2d\sigma_{0+} + d\sigma_{00} - (2\cdot 2d\sigma_{+-} + 2d\sigma_{+0} + 2d\sigma_{0-} + d\sigma_{00})}{2\cdot 2d\sigma_{++} + 2d\sigma_{+0} + 2d\sigma_{0+} + d\sigma_{00} + (2\cdot 2d\sigma_{+-} + 2d\sigma_{+0} + 2d\sigma_{0-} + d\sigma_{00})}$$

Using R_3–invariance

$$A_{YY}^{dd} = \frac{\mathcal{N}_{\uparrow\uparrow} - \mathcal{N}_{\uparrow\downarrow}}{\mathcal{N}_{\uparrow\uparrow} + \mathcal{N}_{\uparrow\downarrow}}$$

In terms of $d\sigma_{\lambda_1\lambda_2}$ one has

$$\mathcal{N}_{\uparrow\uparrow} = L(2 \cdot 2d\sigma_{++} + 2d\sigma_{+0} + 2d\sigma_{0+} + d\sigma_{00}),$$
$$\mathcal{N}_{\uparrow\downarrow} = L(2 \cdot 2d\sigma_{+-} + 2d\sigma_{+0} + 2d\sigma_{0-} + d\sigma_{00}),$$

Using rotational invariance we find

$$\sum_{\sigma_2\sigma_3} | < \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{\sigma_p}(p)\chi_{\sigma_n}(n) > |^2 =$$

$$= \sum_{\sigma_2\sigma_3} | < \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{-\sigma_p}(p)\chi_{-\sigma_n}(n) > |^2,$$

$$d\sigma_{0,1} = d\sigma_{0,-1} = d\sigma_{1,0} = d\sigma_{0,0}$$

$$A_{YY}^{dd} = \frac{1}{2}\frac{d\sigma_{++} - d\sigma_{+-}}{d\sigma_{++} - d\sigma_{+-}} = \frac{1}{2}A_{YY}^{NN}.$$

where

$$A_{YY}^{NN} = \frac{\sum |< \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{+\frac{1}{2}}(p)\chi_{+\frac{1}{2}}(n) > |^2 - \sum |< \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{+\frac{1}{2}}(p)\chi_{-\frac{1}{2}}(n) > |^2}{\sum |< \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{+\frac{1}{2}}(p)\chi_{+\frac{1}{2}}(n) > |^2 - \sum |< \chi_{\sigma_2}(2)\chi_{\sigma_3}(3)|t_{pn}|\chi_{+\frac{1}{2}}(p)\chi_{-\frac{1}{2}}(n) > |^2},$$

where $\sum \equiv \sum_{\sigma_2\sigma_3}$ means summation over σ_2 and σ_3.

OUTLOOK

- We do not have good understanding of the most fundamental process, as hard elastic NN-scattering , in particularly at $\sqrt{s}=3-10GeV$ and their relation to QCD (CT,CCR…)

- Available data on double spin correlation in hard pp->pp are intriguing. Theoretical interpretation is questionable.

- A similar data on A_{NN} in hard pn->pn will provide important independent information on the short-range NN-dynamics

- Measurement of A^{dd}_{yy} in $d^{\uparrow}d^{\uparrow}\rightarrow p(90^{\circ})+n(90^{\circ})+p_s(0)+n_s(0)$ will provide A^{pn}_{yy} in case of the S-wave d.w.f. dominance

D-wave contribution, $q_1 \neq 0$, $q_2 \neq 0$

$$< \chi_{\sigma_1}(1), \chi_{\sigma_p}(p)|\phi_{\lambda_1}(d_1) >= u(q)(\frac{1}{2}\sigma_1 \frac{1}{2}\sigma_p|1\lambda_1) +$$

$$+w(q)\sum_m (2\lambda_1 - 11m|1\lambda_1)(\frac{1}{2}\sigma_1 \frac{1}{2}\sigma_p|1m) Y_{2,\lambda_1 - m}(\hat{\mathbf{q}}).$$

For OZ$\uparrow\uparrow$ $\mathbf{q}$ $\quad Y_{2,\mu}(\hat{\mathbf{q}}) = \delta_{\mu,0} Y_{20}(0,0)$

$$\lambda_1 - m = 0, \lambda_1 = m \qquad (2011|11) = (201-1|1-1) = 1/\sqrt{10}$$

$$Y_{20}(\theta,\phi) = \frac{1}{4}\sqrt{\frac{5}{\pi}}(3\cos^2\theta - 1) = \frac{1}{2}\sqrt{\frac{5}{\pi}}$$

$$(2011|11) = (201-1|1-1) = 1/\sqrt{10}$$

$$Y_{20}(\theta,\phi) = \frac{1}{4}\sqrt{\frac{5}{\pi}}(3\cos^2\theta - 1) = \frac{1}{2}\sqrt{\frac{5}{\pi}}$$

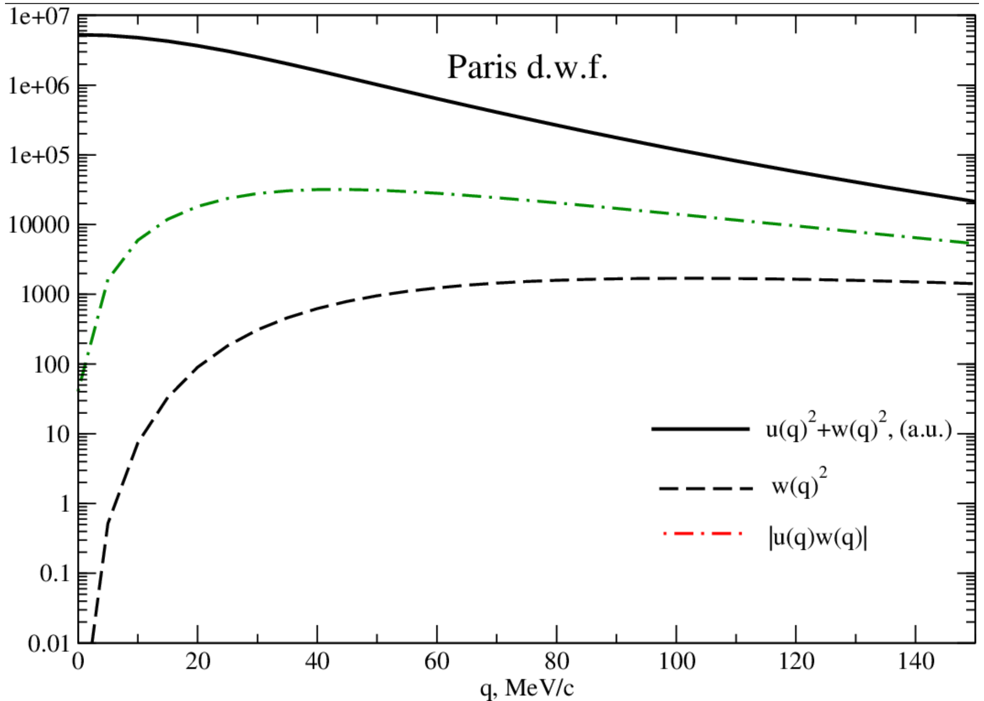
S-wave

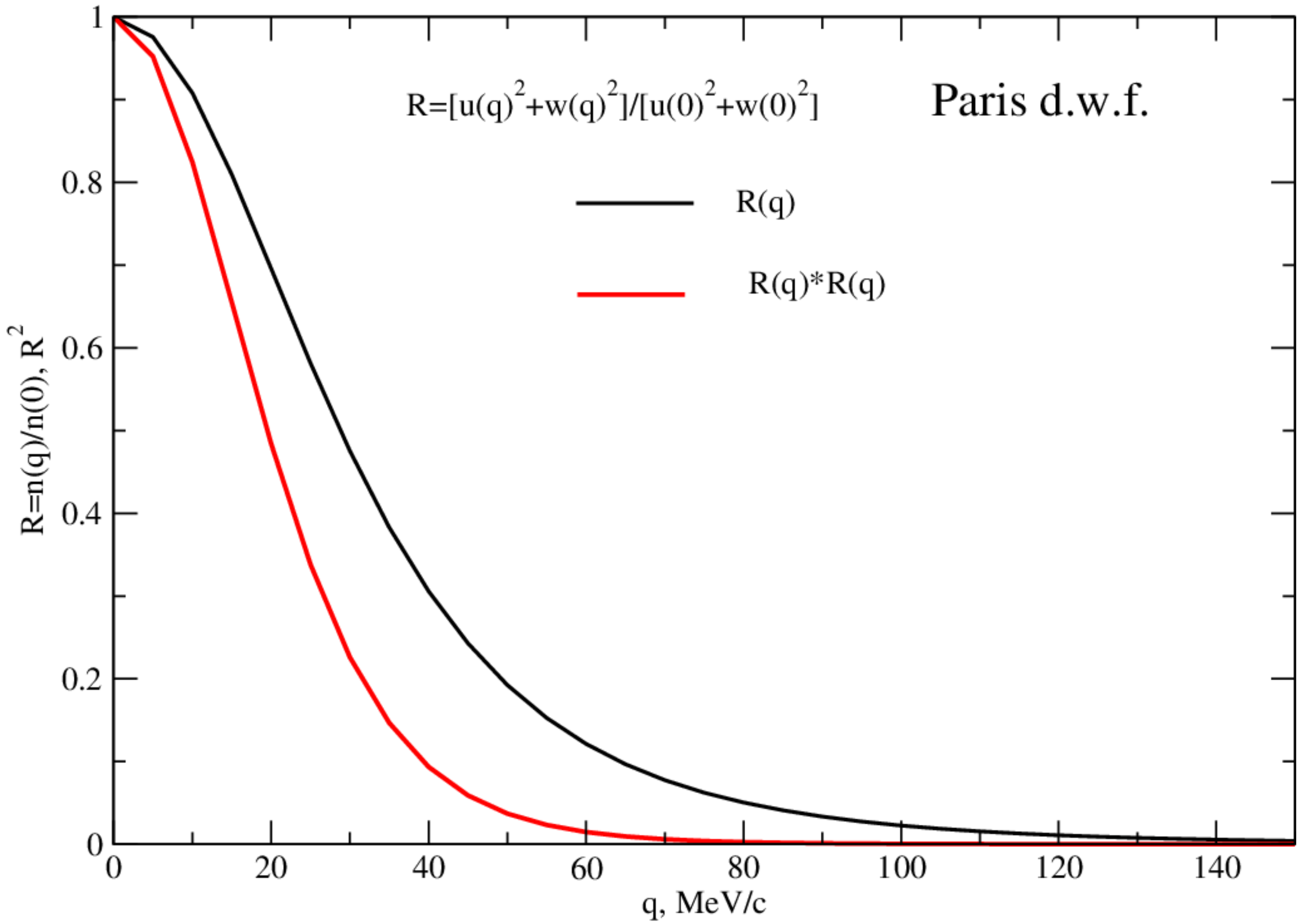
$$u(q)(\frac{1}{2}\sigma_1\frac{1}{2}\sigma_p|1\lambda_1)$$

D-wave

$$w(q)(201\lambda_1|1\lambda_1)(\frac{1}{2}\sigma_1\frac{1}{2}\sigma_p|1\lambda_1)Y_{20}(0)$$

Nucleon momentum distribution in the deuteron





CT for mesons production is well established

$^{4}He(\gamma, \pi p)$

$E_{\gamma} = 2.25 GeV$

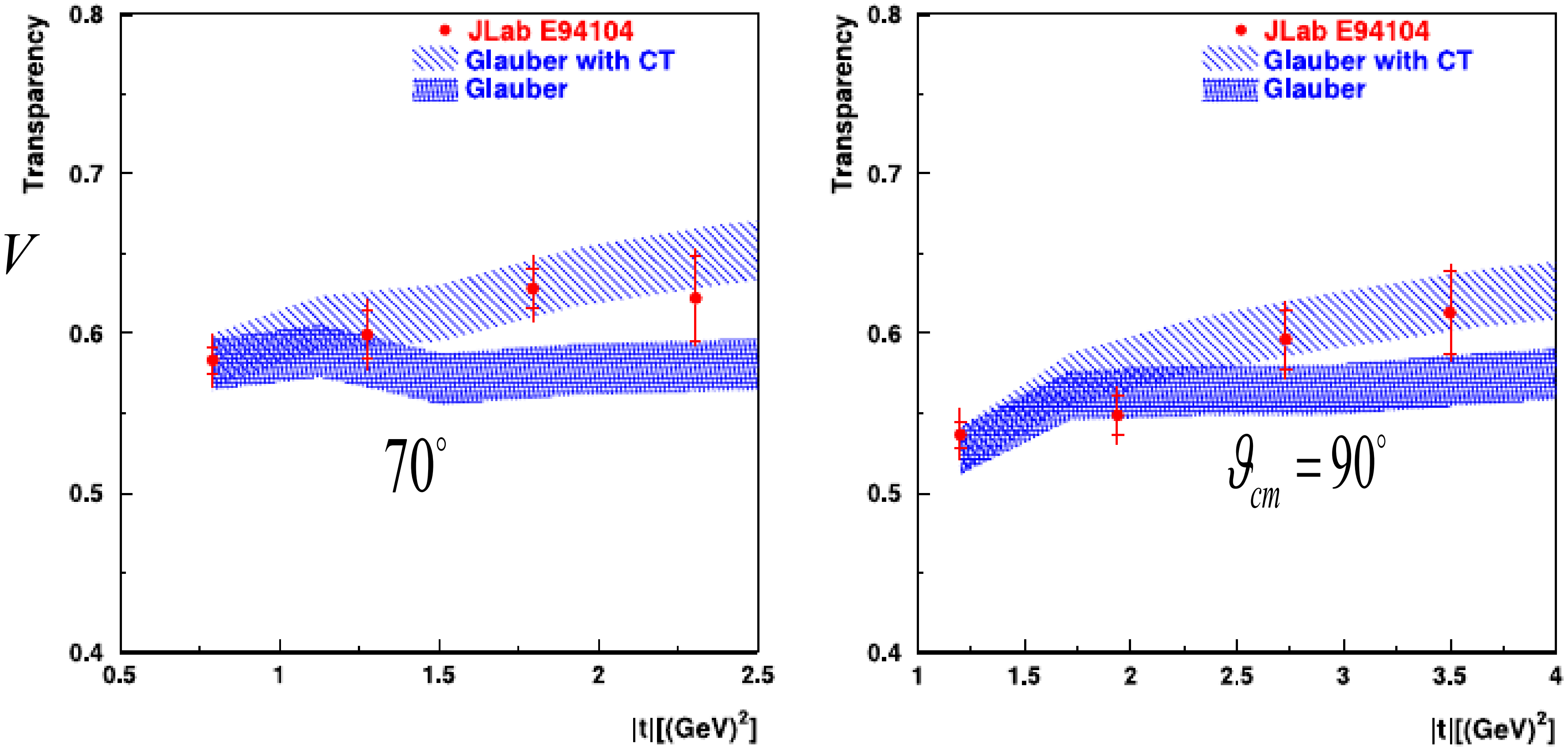


Fig. 13. The nuclear transparency of ^{4}He(γ, $p\pi$) at $\theta^{\pi}_{cm} = 70°$ (left) and $\theta^{\pi}_{cm} = 90°$ (right), as a function of momentum transfer square $|t|$ [80]. The inner error bars shown are statistical uncertainties only, while the outer error bars are statistical and point-to-point systematic uncertainties (2.7%) added in quadrature. In addition there is a 4% normalization/scale systematic uncertainty which leads to a total systematic uncertainty of 4.8%.

Excitation of the deuteron to the D_{03} in pd->pd*(2380)

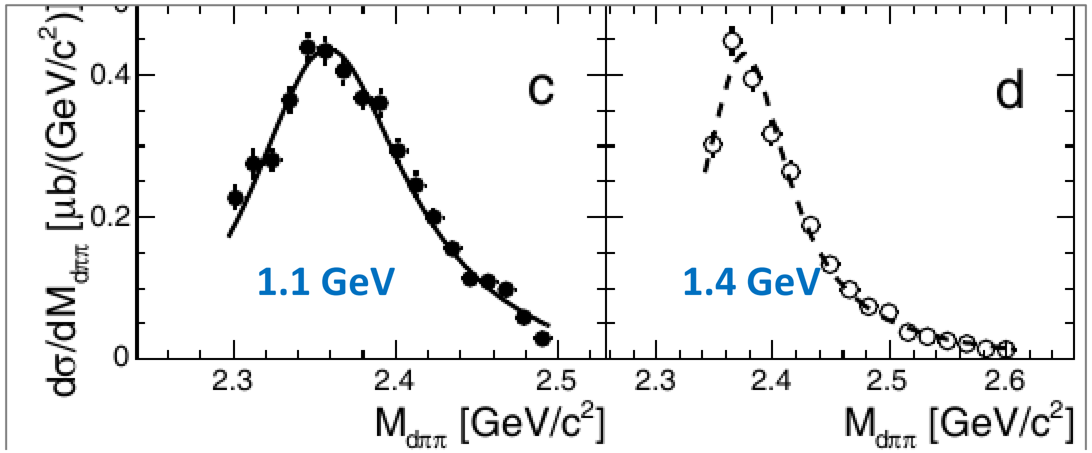
Eur. Phys. J. A (2018) **54**: 206
DOI 10.1140/epja/i2018-12641-0

THE EUROPEAN PHYSICAL JOURNAL A

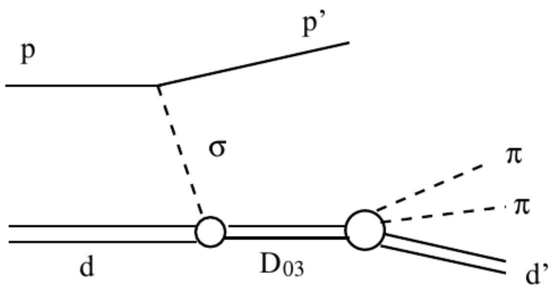
Regular Article – Experimental Physics

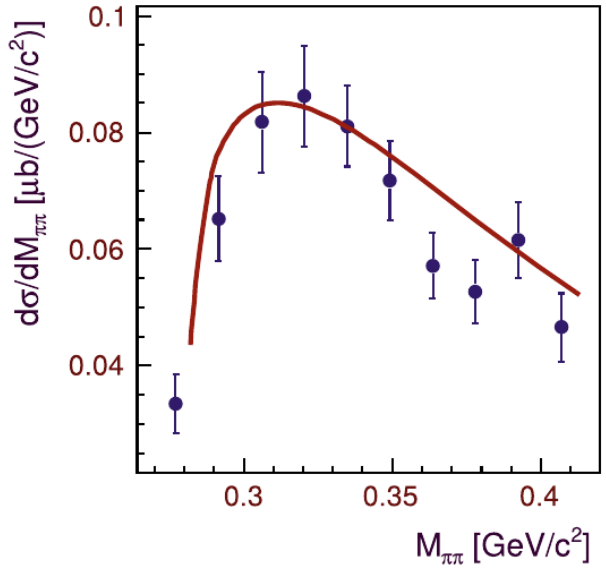
Resonance-like coherent production of a pion pair in the reaction pd → pdππ in the GeV region

V.I. Komarov[1], D. Tsirkov[1,a], T. Azaryan[1], Z. Bagdasarian[2,3], B. Baimurzinova[4,5], S. Barsov[6], S. Dymov[1,2], R. Gebel[2], M. Hartmann[2], A. Kacharava[2], A. Khoukaz[7], A. Kulikov[1], A. Kunsafina[1,4,5], V. Kurbatov[1], Zh. Kurmanaliyev[1,4,5], B. Lorentz[2], G. Macharashvili[3], D. Mchedlishvili[2,3], S. Merzliakov[2], S. Mikirtytchiants[2,6], M. Nioradze[3], H. Ohm[2], F. Rathmann[2], V. Serdyuk[2], V. Shmakova[1], H. Ströher[2], S. Trusov[2,8], Yu. Uzikov[1,9,10], Yu. Valdau[2,6], and C. Wilkin[11]



N.Tursunbaeyv, Y. U. in: Recent Prog.in Few-Body Physics, (Eds. N.A. Orr et al.,2018) Chapt.76, p. 467-470





DIBARYON RESONANCES

D_{IJ}

F.J. Dyson, N.-H. Xuong,
PRL **13**, 815 (1964):

Search for non-strange isovector (I=1) and isotensor (I=2) dibaryons.

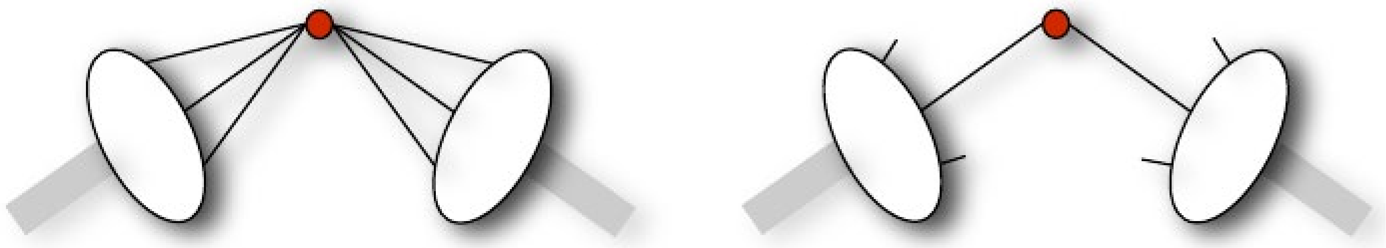
TABLE III. The mass of non-strange dibaryons (MeV).

	Y	S	I	J	$[f]$	M	$M_{exp.}$
D_{01}	2	0	0	1	[33]	1876	1876
D_{10}	2	0	1	0	[42]	1883	1878?
D_{03}	2	0	0	3	[33]	2351	2380
D_{30}	2	0	3	0	[6]	2394	?
D_{12}	2	0	1	2	[42]	2168	2148?
D_{21}	2	0	2	1	[51]	2182	2140?

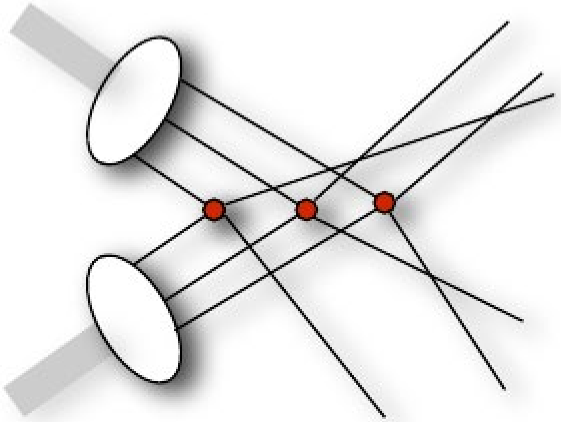
Indication to the D_{21}:
P. Adlarson et al. PRL **121** (2018)

in $pp \to pp\pi^+\pi^-$
at 1 GeV

P. Jain, B. Pire, J.P. Ralston, Physics 2022, 4, 579-589



QC



Landshoff