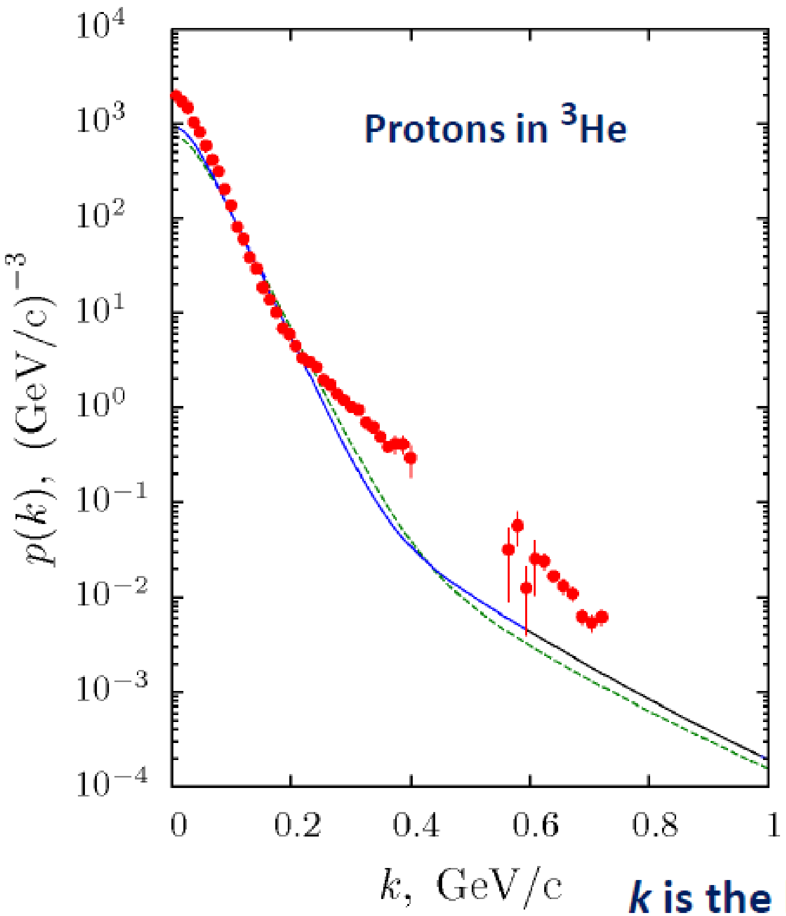
Поляризованный гелий-3
и предыстория…

Е.А.С., Дубна, 08.07.2021

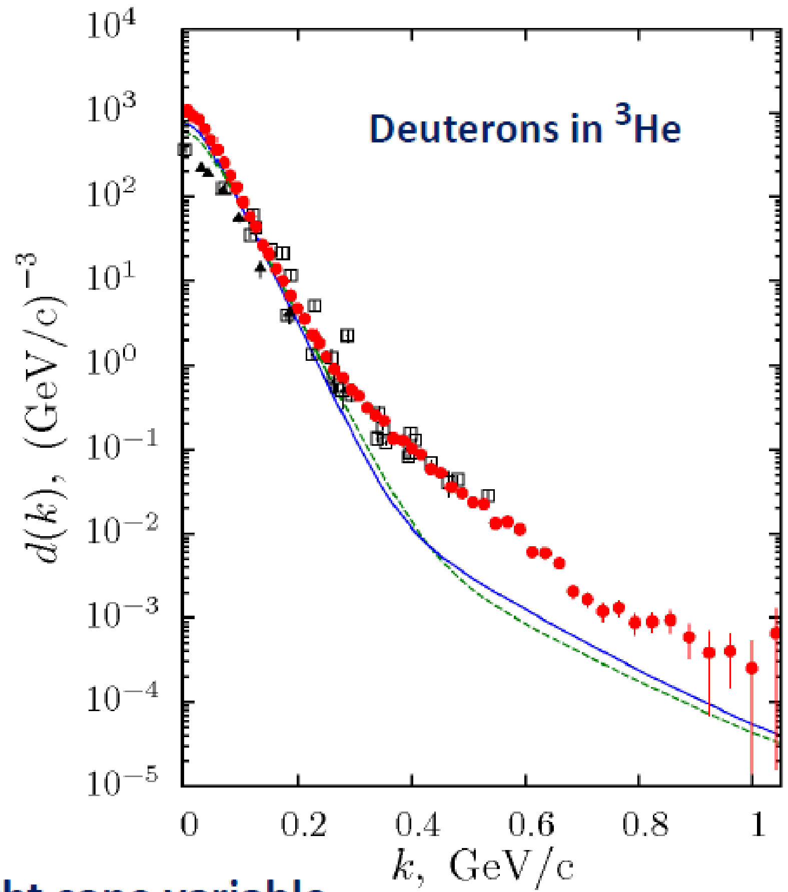
Data for ^{3}He structure (probed by hadrons)

Неполяризованный ^{3}He
(опыты на Синхрофазотроне)

$A(^{3}He,p)X$, 0°, Dubna (1987)



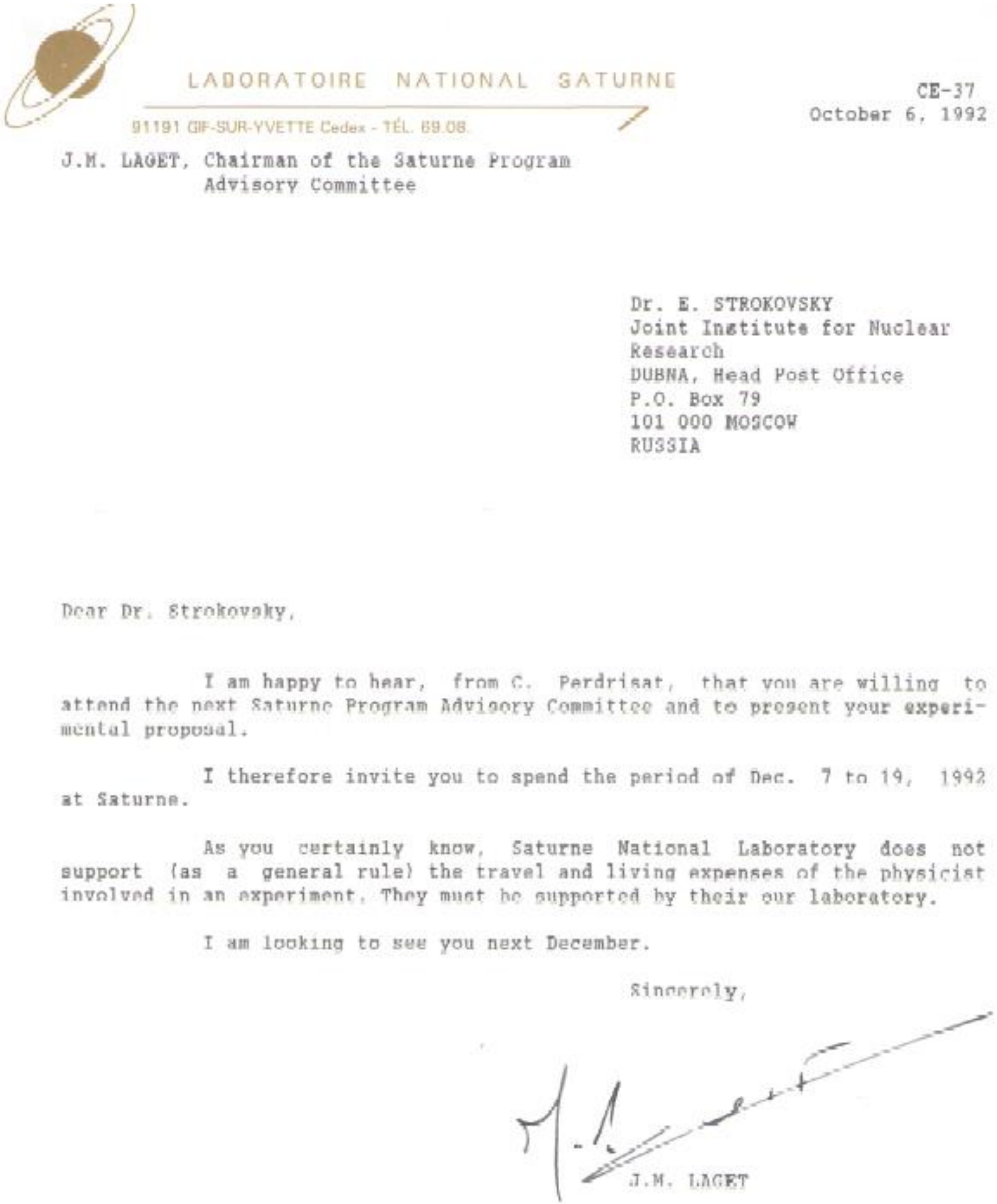
$A(^{3}He,d)X$, 0°, Dubna (1987)
^{3}He(p,pd)p & ^{3}He(p,pp)d, TRIUMF (1972)
^{3}He(p,pd)p, SREL (1985)



***k* is the light cone variable**

E.A.Strokovsky, DSPIN-13, Dubna, Oct. 2013

Поляризованный пучок 3He – наше предложение для «Сатурна»: 1992-1993 г.г.



LABORATOIRE NATIONAL SATURNE
91191 GIF-SUR-YVETTE Cedex - TÉL. 69.08.

CE-37
October 6, 1992

J.M. LAGET, Chairman of the Saturne Program
Advisory Committee

Dr. E. STROKOVSKY
Joint Institute for Nuclear
Research
DUBNA, Head Post Office
P.O. Box 79
101 000 MOSCOW
RUSSIA

Dear Dr. Strokovsky,

I am happy to hear, from C. Perdrisat, that you are willing to attend the next Saturne Program Advisory Committee and to present your experimental proposal.

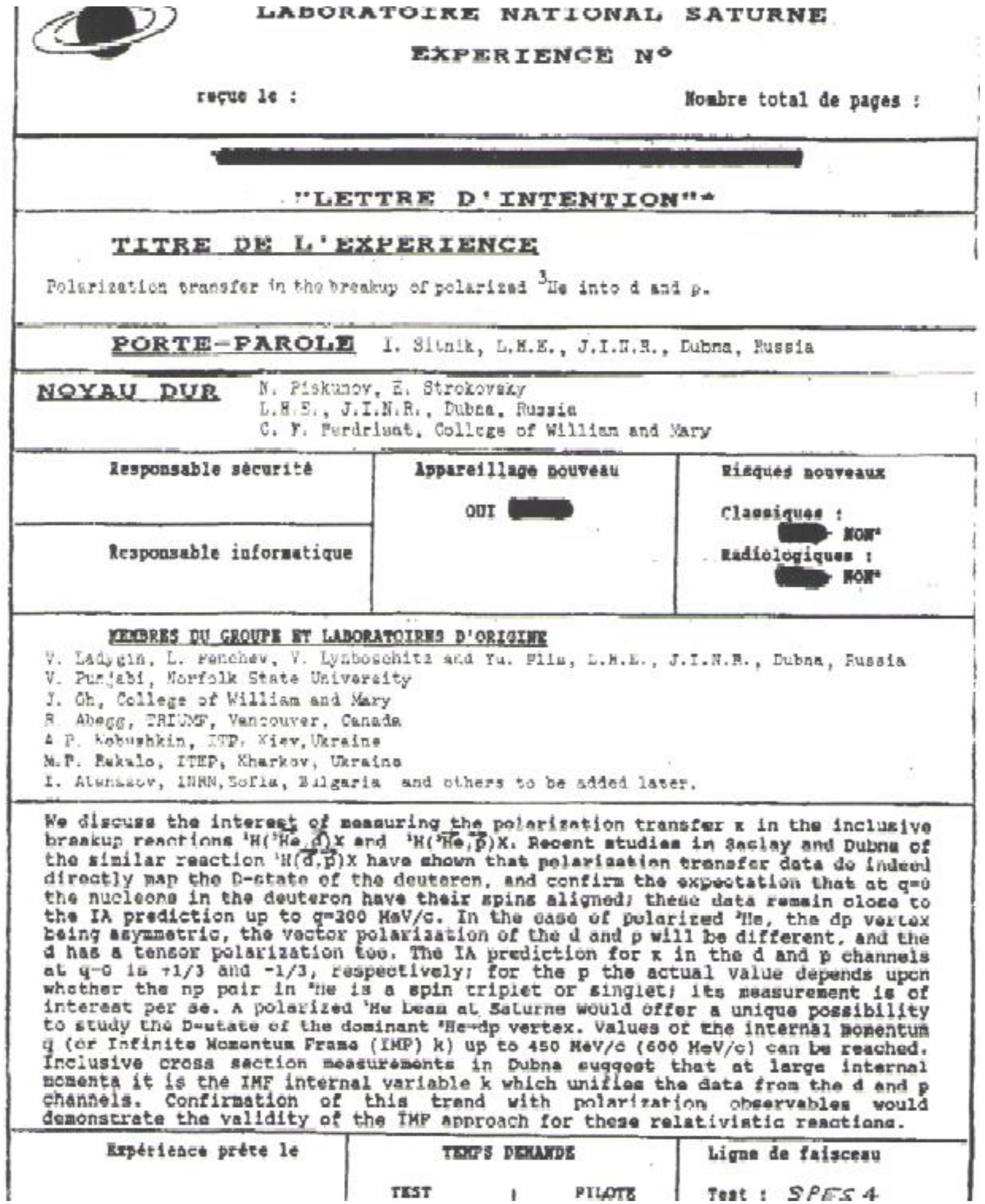
I therefore invite you to spend the period of Dec. 7 to 19, 1992 at Saturne.

As you certainly know, Saturne National Laboratory does not support (as a general rule) the travel and living expenses of the physicist involved in an experiment. They must be supported by their our laboratory.

I am looking to see you next December.

Sincerely,

J.M. LAGET



LABORATOIRE NATIONAL SATURNE
EXPERIENCE N°

reçue le :
Nombre total de pages :

[redacted]

"LETTRE D'INTENTION"*

TITRE DE L'EXPERIENCE

Polarization transfer in the breakup of polarized ^{3}He into d and p.

PORTE-PAROLE I. Sitnik, L.H.E., J.I.N.R., Dubna, Russia

NOYAU DUR N. Piskunov, E. Strokovsky
L.H.E., J.I.N.R., Dubna, Russia
C. F. Perdrisat, College of William and Mary

Responsable sécurité	Appareillage nouveau OUI [redacted]	Risques nouveaux Classiques : [redacted] NON* Radiologiques : [redacted] NON*
Responsable informatique		

MEMBRES DU GROUPE ET LABORATOIRES D'ORIGINE

V. Ladygin, L. Penchev, V. Lyuboschitz and Yu. Pilu, L.H.E., J.I.N.R., Dubna, Russia
V. Punjabi, Norfolk State University
J. Oh, College of William and Mary
R. Abegg, TRIUMF, Vancouver, Canada
A P. Kobushkin, ITP, Kiev, Ukraine
M.P. Rekalo, ITEP, Kharkov, Ukraine
I. Atanasov, INRN, Sofia, Bulgaria and others to be added later.

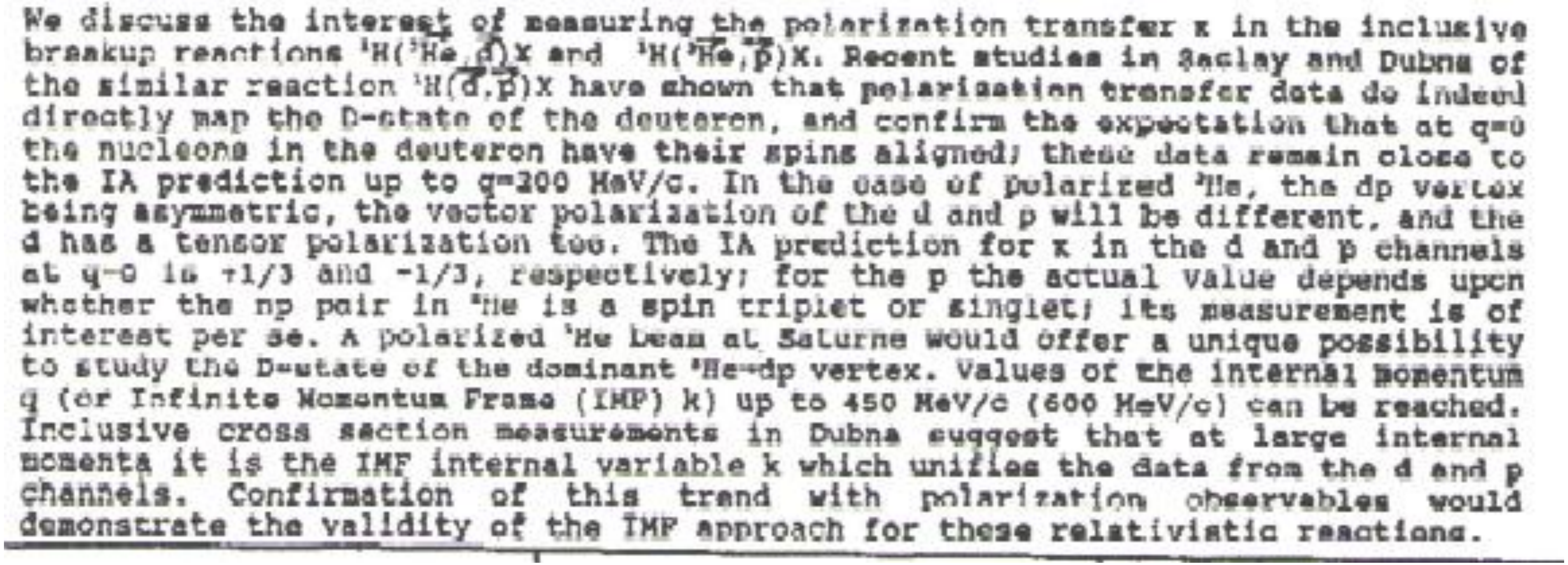
We discuss the interest of measuring the polarization transfer κ in the inclusive breakup reactions $^{1}H(^{3}\vec{He},\vec{d})X$ and $^{1}H(^{3}\vec{He},\vec{p})X$. Recent studies in Saclay and Dubna of the similar reaction $^{1}H(\vec{d},\vec{p})X$ have shown that polarization transfer data do indeed directly map the D-state of the deuteron, and confirm the expectation that at q=0 the nucleons in the deuteron have their spins aligned; these data remain close to the IA prediction up to q=200 MeV/c. In the case of polarized ^{3}He, the dp vertex being asymmetric, the vector polarization of the d and p will be different, and the d has a tensor polarization too. The IA prediction for κ in the d and p channels at q=0 is +1/3 and -1/3, respectively; for the p the actual value depends upon whether the np pair in ^{3}He is a spin triplet or singlet; its measurement is of interest per se. A polarized ^{3}He beam at Saturne would offer a unique possibility to study the D-state of the dominant ^{3}He→dp vertex. Values of the internal momentum q (or Infinite Momentum Frame (IMF) k) up to 450 MeV/c (600 MeV/c) can be reached. Inclusive cross section measurements in Dubna suggest that at large internal momenta it is the IMF internal variable k which unifies the data from the d and p channels. Confirmation of this trend with polarization observables would demonstrate the validity of the IMF approach for these relativistic reactions.

Expérience prête le	TEMPS DEMANDE TEST | PILOTE	Ligne de faisceau Test : SPES 4

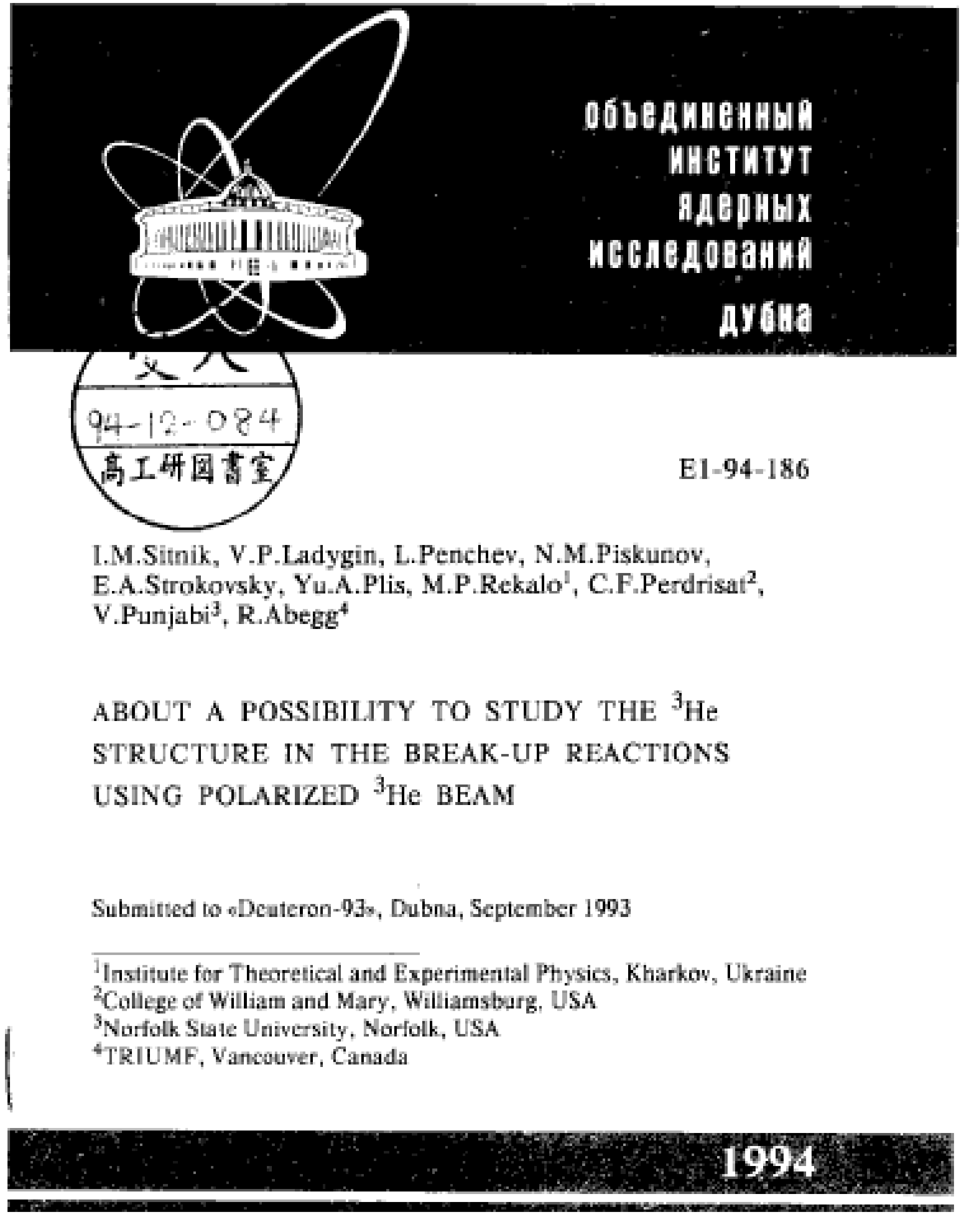
Е.А.С., Дубна, 08.07.2021

Polarization transfer in the breakup of polarized ^3He into p and d

Saclay Letter of Intent n^o264



We discuss the interest of measuring the polarization transfer κ in the inclusive breakup reactions $^1H(^3\vec{He},\vec{d})X$ and $^1H(^3\vec{He},\vec{p})X$. Recent studies in Saclay and Dubna of the similar reaction $^1H(\vec{d},\vec{p})X$ have shown that polarisation transfer data do indeed directly map the D-state of the deuteron, and confirm the expectation that at $q=0$ the nucleons in the deuteron have their spins aligned; these data remain close to the IA prediction up to $q=200$ MeV/c. In the case of polarized ^3He, the dp vertex being asymmetric, the vector polarization of the d and p will be different, and the d has a tensor polarization too. The IA prediction for κ in the d and p channels at $q=0$ is $+1/3$ and $-1/3$, respectively; for the p the actual value depends upon whether the np pair in ^3He is a spin triplet or singlet; its measurement is of interest per se. A polarized ^3He beam at Saturne would offer a unique possibility to study the D-state of the dominant $^3He \to dp$ vertex. Values of the internal momentum q (or Infinite Momentum Frame (IMF) k) up to 450 MeV/c (600 MeV/c) can be reached. Inclusive cross section measurements in Dubna suggest that at large internal momenta it is the IMF internal variable k which unifies the data from the d and p channels. Confirmation of this trend with polarization observables would demonstrate the validity of the IMF approach for these relativistic reactions.



**ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
ДУБНА**

E1-94-186

I.M.Sitnik, V.P.Ladygin, L.Penchev, N.M.Piskunov,
E.A.Strokovsky, Yu.A.Plis, M.P.Rekalo[1], C.F.Perdrisat[2],
V.Punjabi[3], R.Abegg[4]

ABOUT A POSSIBILITY TO STUDY THE ^{3}He STRUCTURE IN THE BREAK-UP REACTIONS USING POLARIZED ^{3}He BEAM

Submitted to «Deuteron-93», Dubna, September 1993

---

[1] Institute for Theoretical and Experimental Physics, Kharkov, Ukraine
[2] College of William and Mary, Williamsburg, USA
[3] Norfolk State University, Norfolk, USA
[4] TRIUMF, Vancouver, Canada

1994

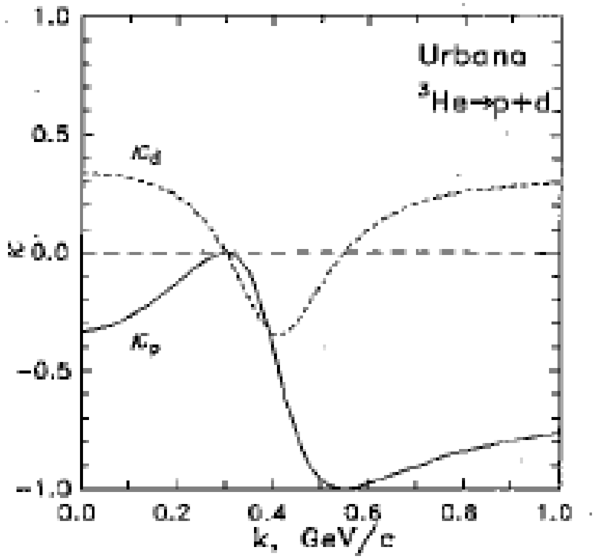


Fig.6 The predicted polarization transfers of $^3He \rightarrow d$ and $^3He \rightarrow p$ reactions (in framework of IA) for the $(d+p)$ vertex of ^3He (using calculation and formulas from text).

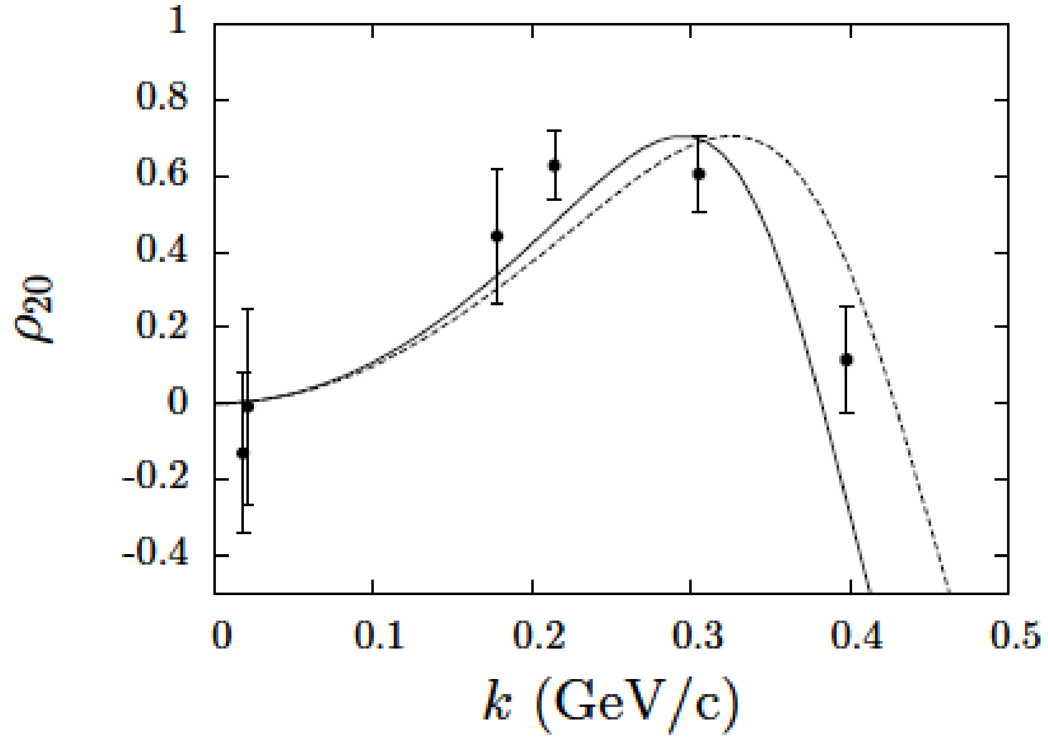


FIG. 9: Deuteron alignment ρ_{20} calculated with the ^{3}He wave functions for the Paris (solid) and CD-Bonn (dashed) potentials compared with experimental data. The signs of the data points [10] are reversed to bring them into accordance with the preliminary results [11] of the same experiment, as well as with the sign of experimental data on the D_2 parameter for ^{3}He.

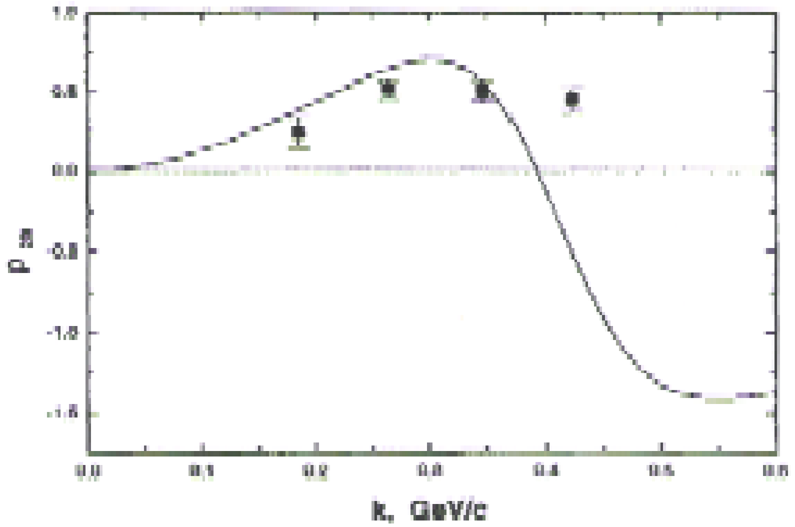
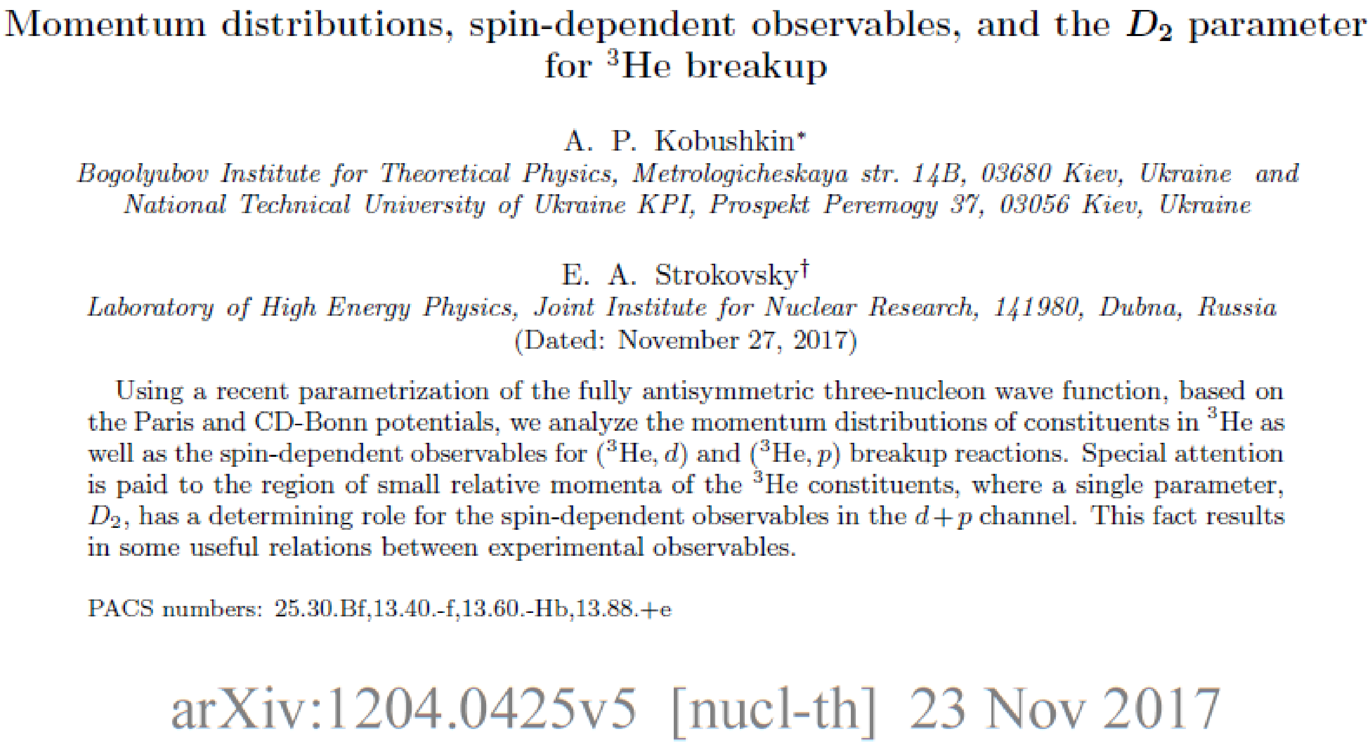


Fig. 2. Deuteron alignment ρ_{20} in inclusive ^{1}H(^{3}He, $\vec{d}$)X [9]. The line is calculated in IA with ^{3}He wave function based on Urbana potential [33,40]

[10] I. M. Sitnik *et al.*, Phys. Rev. C **84**, 034006 (2011).
[11] I. M. Sitnik *et al.*, Nucl. Phys. A **663**, 443 (2000).

Е.А.С., Дубна, 08.07.2021



Momentum distributions, spin-dependent observables, and the D_2 parameter for ^{3}He breakup

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Bogolyubov Institute for Theoretical Physics, Metrologicheskaya str. 14B, 03680 Kiev, Ukraine and
National Technical University of Ukraine KPI, Prospekt Peremogy 37, 03056 Kiev, Ukraine

E. A. Strokovsky†
Laboratory of High Energy Physics, Joint Institute for Nuclear Research, 141980, Dubna, Russia
(Dated: November 27, 2017)

Using a recent parametrization of the fully antisymmetric three-nucleon wave function, based on the Paris and CD-Bonn potentials, we analyze the momentum distributions of constituents in ^{3}He as well as the spin-dependent observables for (^{3}He, d) and (^{3}He, p) breakup reactions. Special attention is paid to the region of small relative momenta of the ^{3}He constituents, where a single parameter, D_2, has a determining role for the spin-dependent observables in the $d+p$ channel. This fact results in some useful relations between experimental observables.

PACS numbers: 25.30.Bf,13.40.-f,13.60.-Hb,13.88.+e

arXiv:1204.0425v5 [nucl-th] 23 Nov 2017

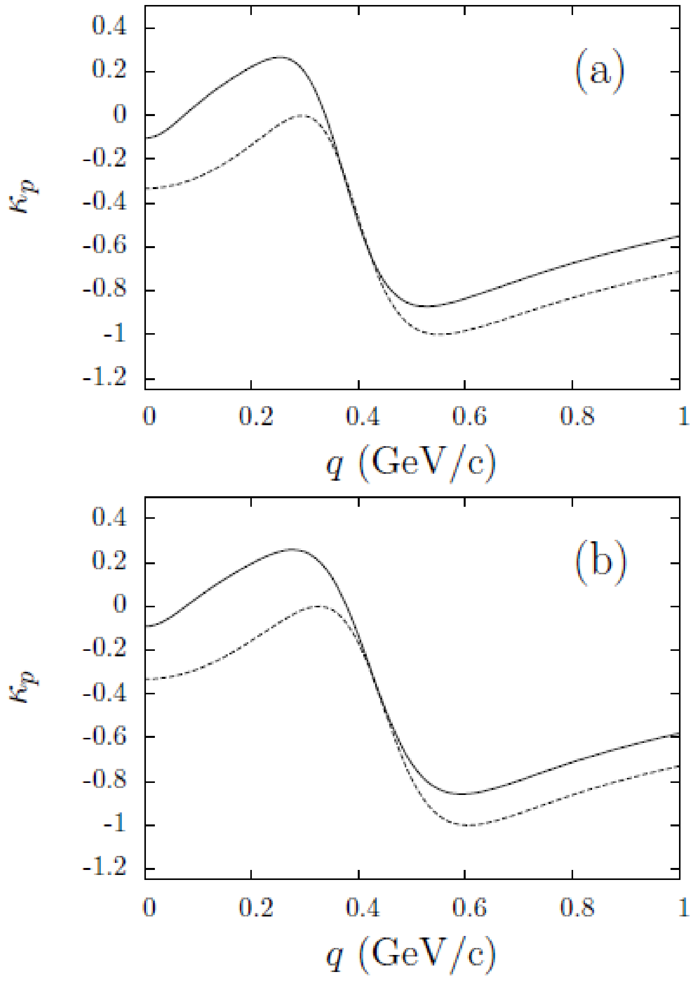
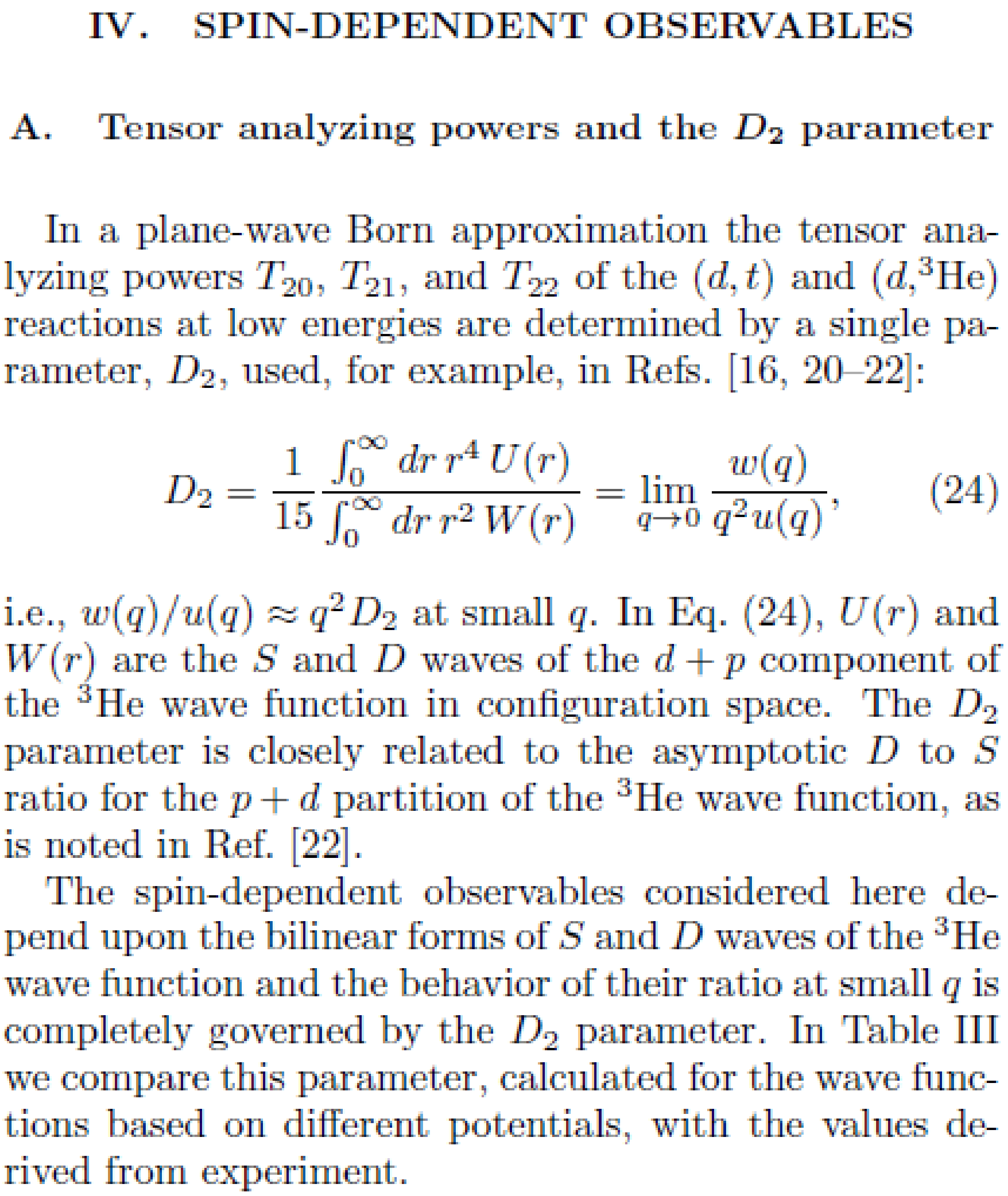


FIG. 7: The coefficient of polarization transfer from ^{3}He to the proton. The ^{3}He wave function used is based on the Paris potential (a) and the CD-Bonn potential (b). Solid line: full wave function. Short-dashed line: only the $d+p$ projection (i.e., the $\widetilde{\kappa}_p$).



IV. SPIN-DEPENDENT OBSERVABLES

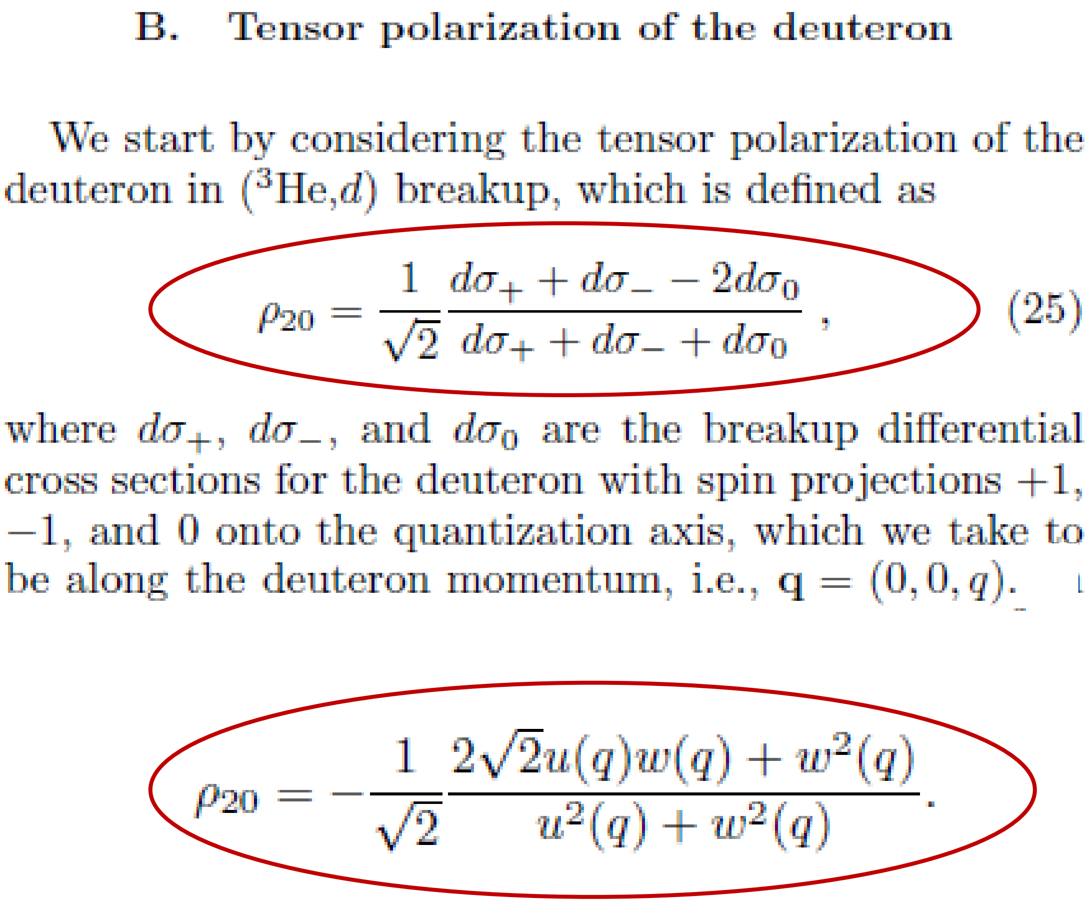
A. Tensor analyzing powers and the D_2 parameter

In a plane-wave Born approximation the tensor analyzing powers T_{20}, T_{21}, and T_{22} of the (d,t) and $(d,{}^3\mathrm{He})$ reactions at low energies are determined by a single parameter, D_2, used, for example, in Refs. [16, 20–22]:

$$D_2 = \frac{1}{15}\frac{\int_0^\infty dr\, r^4\, U(r)}{\int_0^\infty dr\, r^2\, W(r)} = \lim_{q\to 0}\frac{w(q)}{q^2 u(q)}, \qquad (24)$$

i.e., $w(q)/u(q) \approx q^2 D_2$ at small q. In Eq. (24), $U(r)$ and $W(r)$ are the S and D waves of the $d+p$ component of the ^{3}He wave function in configuration space. The D_2 parameter is closely related to the asymptotic D to S ratio for the $p+d$ partition of the ^{3}He wave function, as is noted in Ref. [22].

The spin-dependent observables considered here depend upon the bilinear forms of S and D waves of the ^{3}He wave function and the behavior of their ratio at small q is completely governed by the D_2 parameter. In Table III we compare this parameter, calculated for the wave functions based on different potentials, with the values derived from experiment.



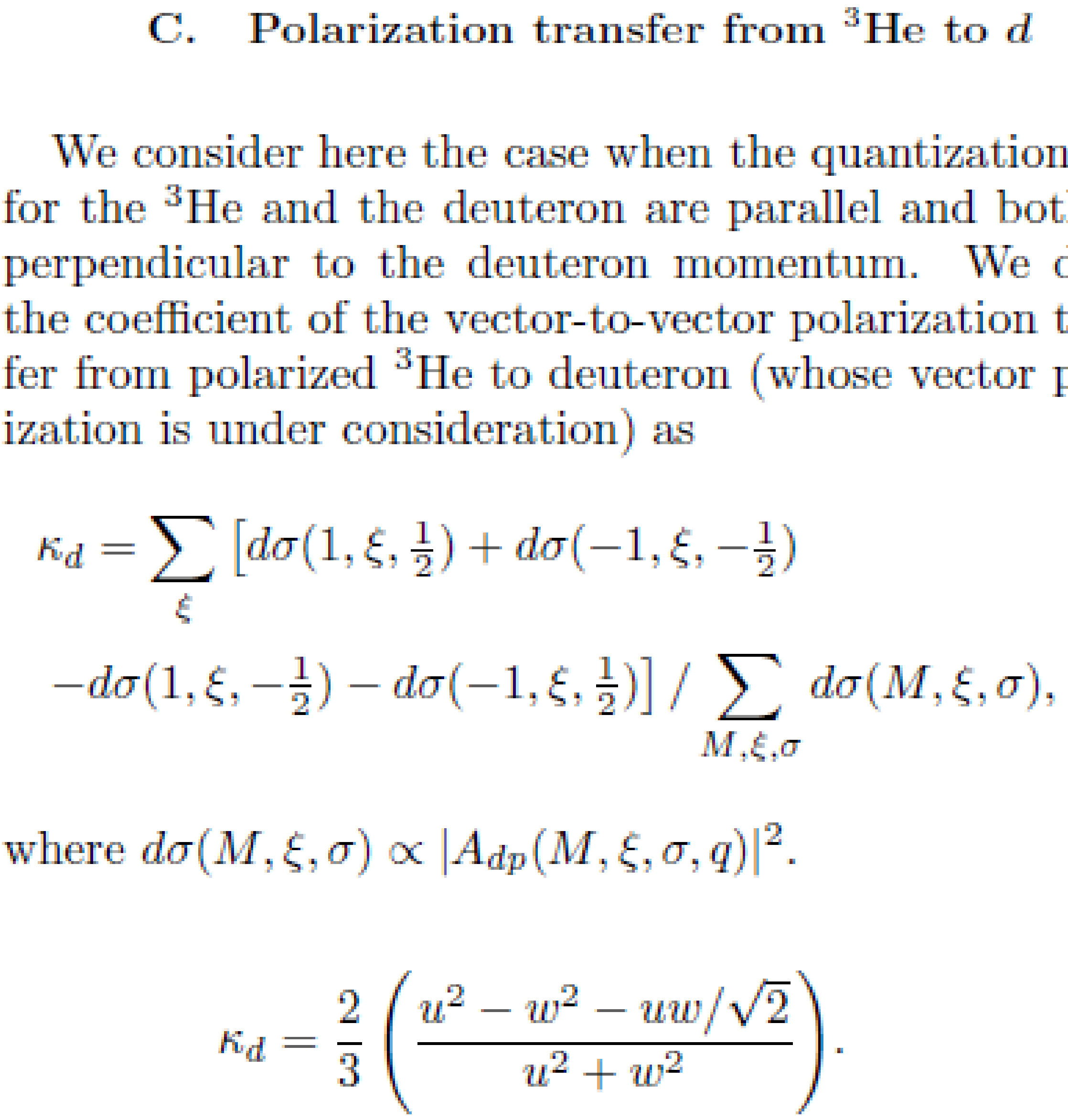
B. Tensor polarization of the deuteron

We start by considering the tensor polarization of the deuteron in $({}^3\mathrm{He},d)$ breakup, which is defined as

$$\rho_{20} = \frac{1}{\sqrt{2}}\frac{d\sigma_+ + d\sigma_- - 2d\sigma_0}{d\sigma_+ + d\sigma_- + d\sigma_0}\,, \qquad (25)$$

where $d\sigma_+$, $d\sigma_-$, and $d\sigma_0$ are the breakup differential cross sections for the deuteron with spin projections $+1$, -1, and 0 onto the quantization axis, which we take to be along the deuteron momentum, i.e., $\mathbf{q} = (0,0,q)$.

$$\rho_{20} = -\frac{1}{\sqrt{2}}\frac{2\sqrt{2}u(q)w(q) + w^2(q)}{u^2(q) + w^2(q)}.$$



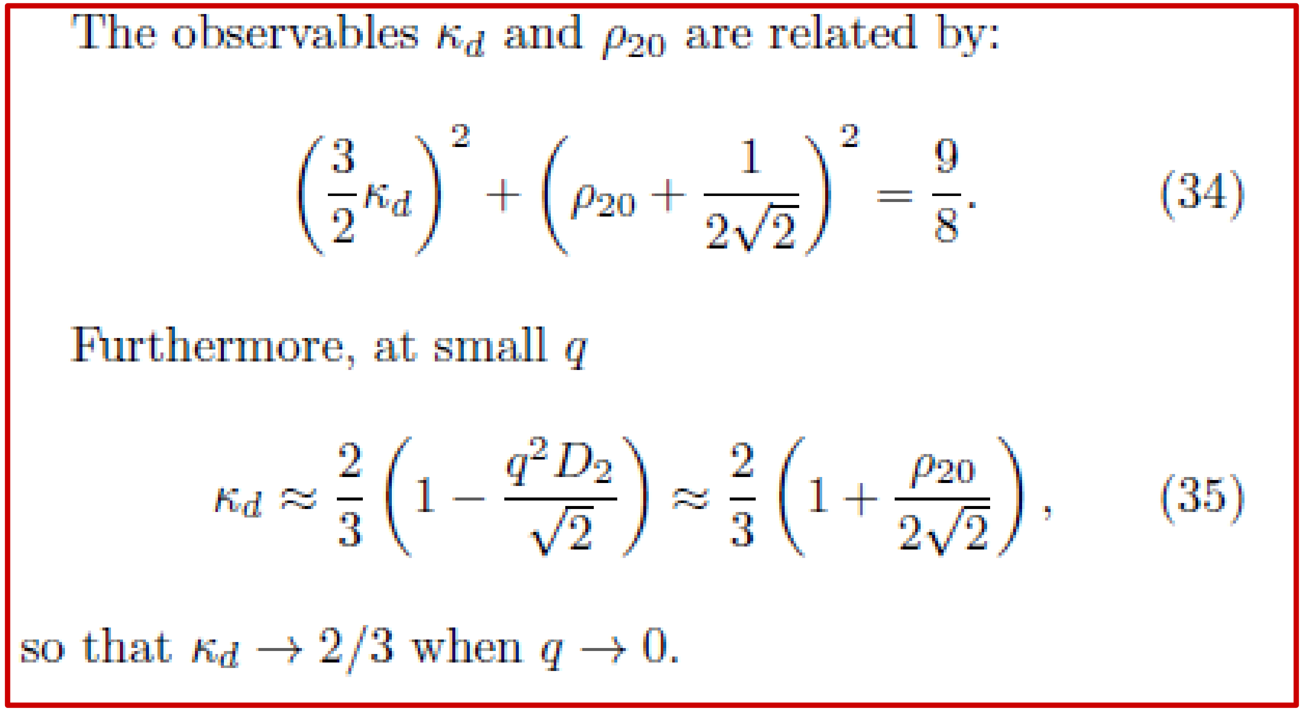
C. Polarization transfer from ^{3}He to d

We consider here the case when the quantization axes for the ^{3}He and the deuteron are parallel and both are perpendicular to the deuteron momentum. We define the coefficient of the vector-to-vector polarization transfer from polarized ^{3}He to deuteron (whose vector polarization is under consideration) as

$$\kappa_d = \sum_{\xi} \Big[d\sigma(1,\xi,\tfrac{1}{2}) + d\sigma(-1,\xi,-\tfrac{1}{2}) \\ - d\sigma(1,\xi,-\tfrac{1}{2}) - d\sigma(-1,\xi,\tfrac{1}{2}) \Big] \Big/ \sum_{M,\xi,\sigma} d\sigma(M,\xi,\sigma),$$

where $d\sigma(M,\xi,\sigma) \propto |A_{dp}(M,\xi,\sigma,q)|^2$.

$$\kappa_d = \frac{2}{3}\left(\frac{u^2 - w^2 - uw/\sqrt{2}}{u^2 + w^2}\right).$$



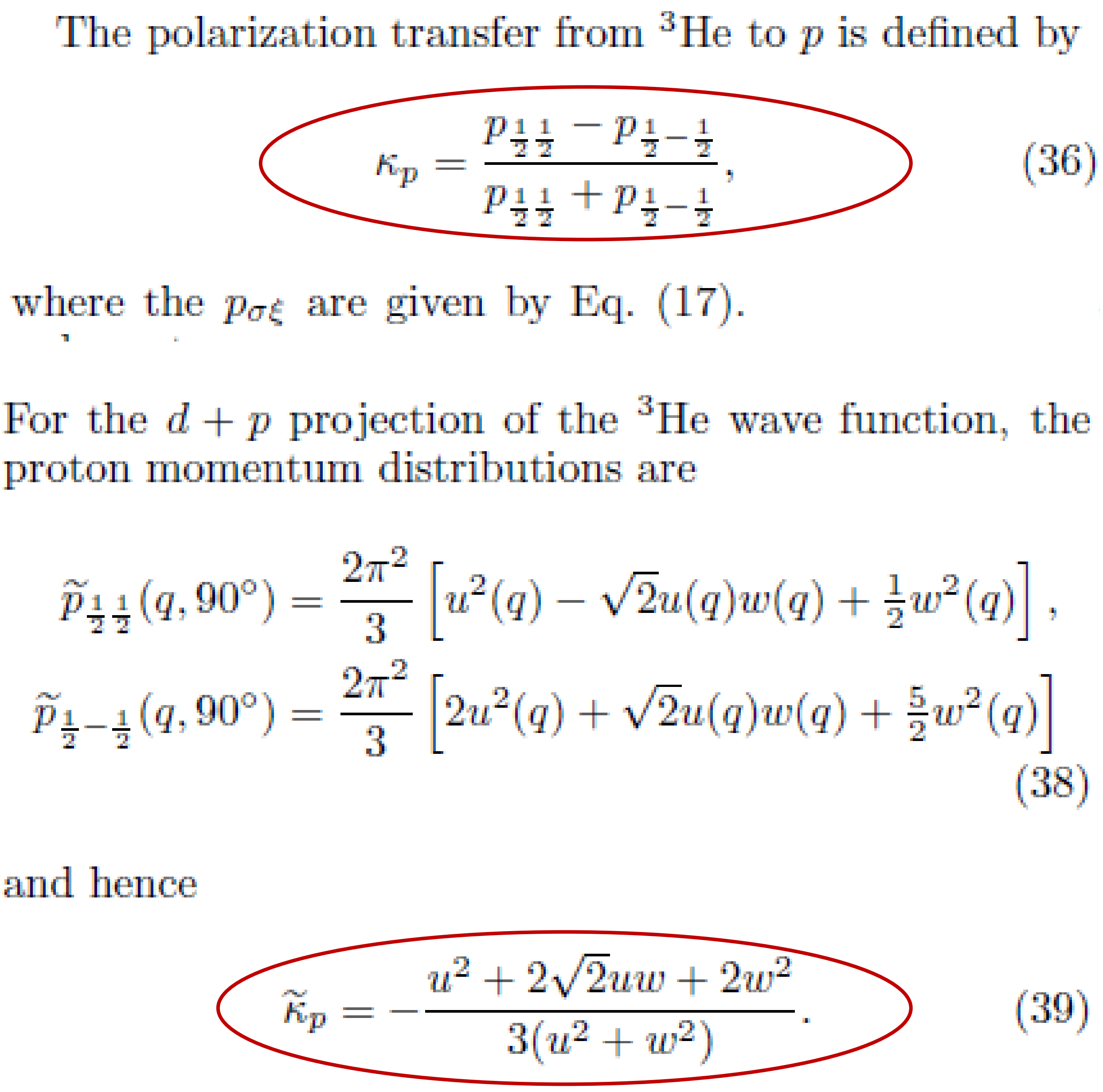
The observables κ_d and ρ_{20} are related by:

$$\left(\frac{3}{2}\kappa_d\right)^2 + \left(\rho_{20} + \frac{1}{2\sqrt{2}}\right)^2 = \frac{9}{8}. \qquad (34)$$

Furthermore, at small q

$$\kappa_d \approx \frac{2}{3}\left(1 - \frac{q^2 D_2}{\sqrt{2}}\right) \approx \frac{2}{3}\left(1 + \frac{\rho_{20}}{2\sqrt{2}}\right), \qquad (35)$$

so that $\kappa_d \to 2/3$ when $q \to 0$.



The polarization transfer from ^{3}He to p is defined by

$$\kappa_p = \frac{p_{\frac{1}{2}\frac{1}{2}} - p_{\frac{1}{2}-\frac{1}{2}}}{p_{\frac{1}{2}\frac{1}{2}} + p_{\frac{1}{2}-\frac{1}{2}}}, \qquad (36)$$

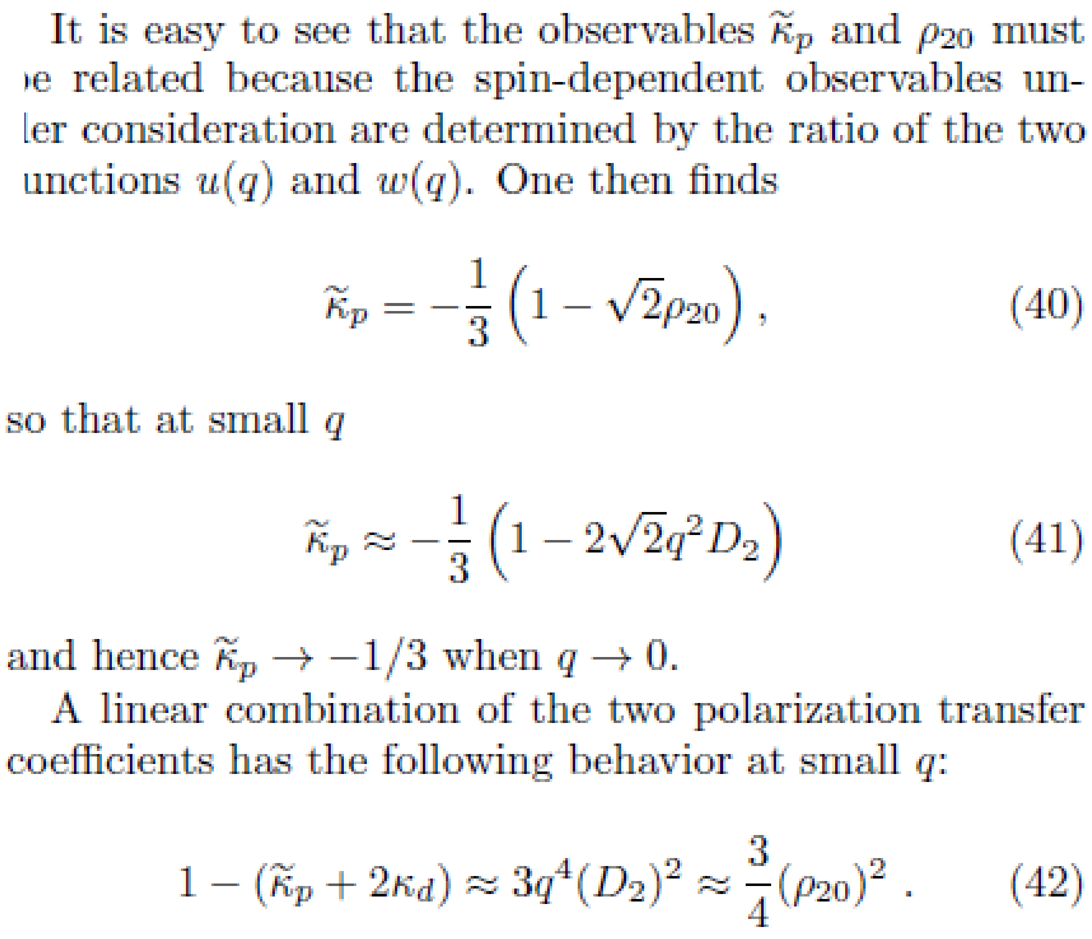
where the $p_{\sigma\xi}$ are given by Eq. (17).

For the $d + p$ projection of the ^{3}He wave function, the proton momentum distributions are

$$\widetilde{p}_{\frac{1}{2}\frac{1}{2}}(q, 90^\circ) = \frac{2\pi^2}{3}\left[u^2(q) - \sqrt{2}u(q)w(q) + \tfrac{1}{2}w^2(q)\right],$$
$$\widetilde{p}_{\frac{1}{2}-\frac{1}{2}}(q, 90^\circ) = \frac{2\pi^2}{3}\left[2u^2(q) + \sqrt{2}u(q)w(q) + \tfrac{5}{2}w^2(q)\right] \qquad (38)$$

and hence

$$\widetilde{\kappa}_p = -\frac{u^2 + 2\sqrt{2}uw + 2w^2}{3(u^2 + w^2)}. \qquad (39)$$



It is easy to see that the observables $\widetilde{\kappa}_p$ and ρ_{20} must e related because the spin-dependent observables un-ler consideration are determined by the ratio of the two unctions $u(q)$ and $w(q)$. One then finds

$$\widetilde{\kappa}_p = -\frac{1}{3}\left(1 - \sqrt{2}\rho_{20}\right), \qquad (40)$$

so that at small q

$$\widetilde{\kappa}_p \approx -\frac{1}{3}\left(1 - 2\sqrt{2}q^2 D_2\right) \qquad (41)$$

and hence $\widetilde{\kappa}_p \to -1/3$ when $q \to 0$.

A linear combination of the two polarization transfer coefficients has the following behavior at small q:

$$1 - (\widetilde{\kappa}_p + 2\kappa_d) \approx 3q^4(D_2)^2 \approx \frac{3}{4}(\rho_{20})^2\,. \qquad (42)$$

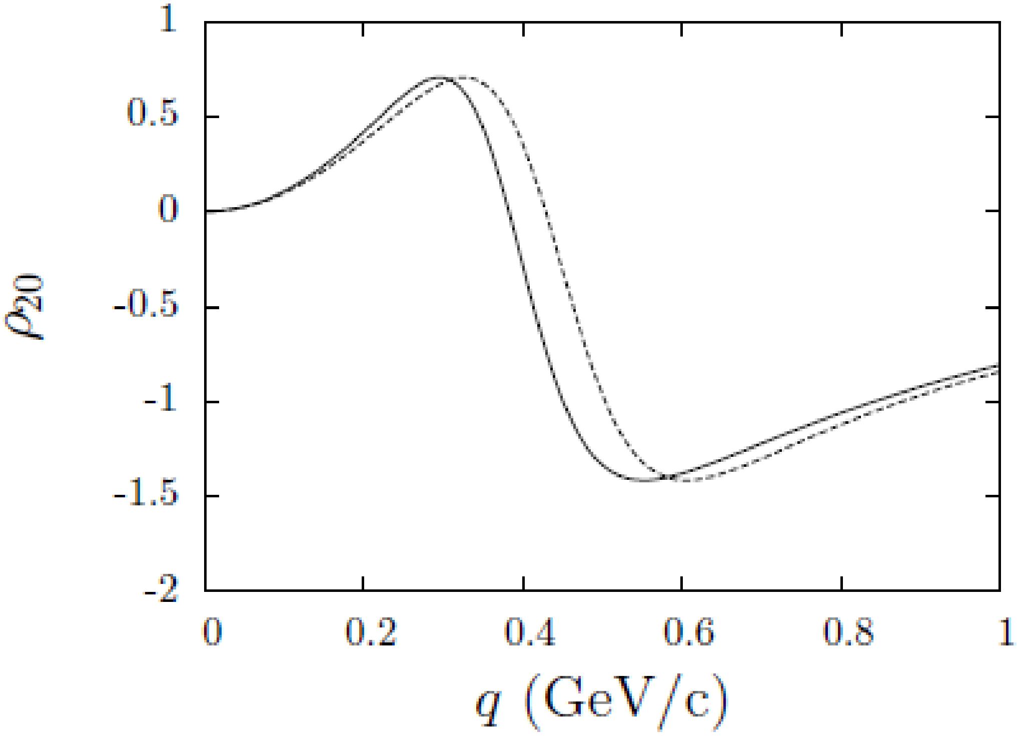


FIG. 5: Deuteron alignment calculated with ^{3}He wave functions for the Paris (solid) and CD-Bonn (dashed) potentials.

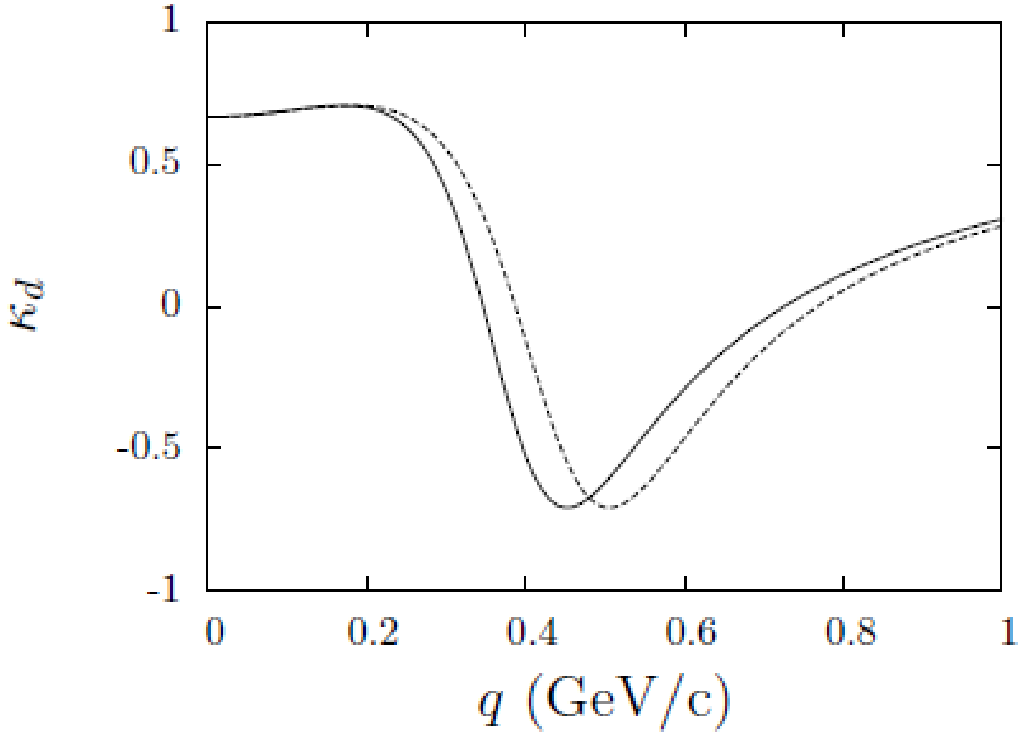
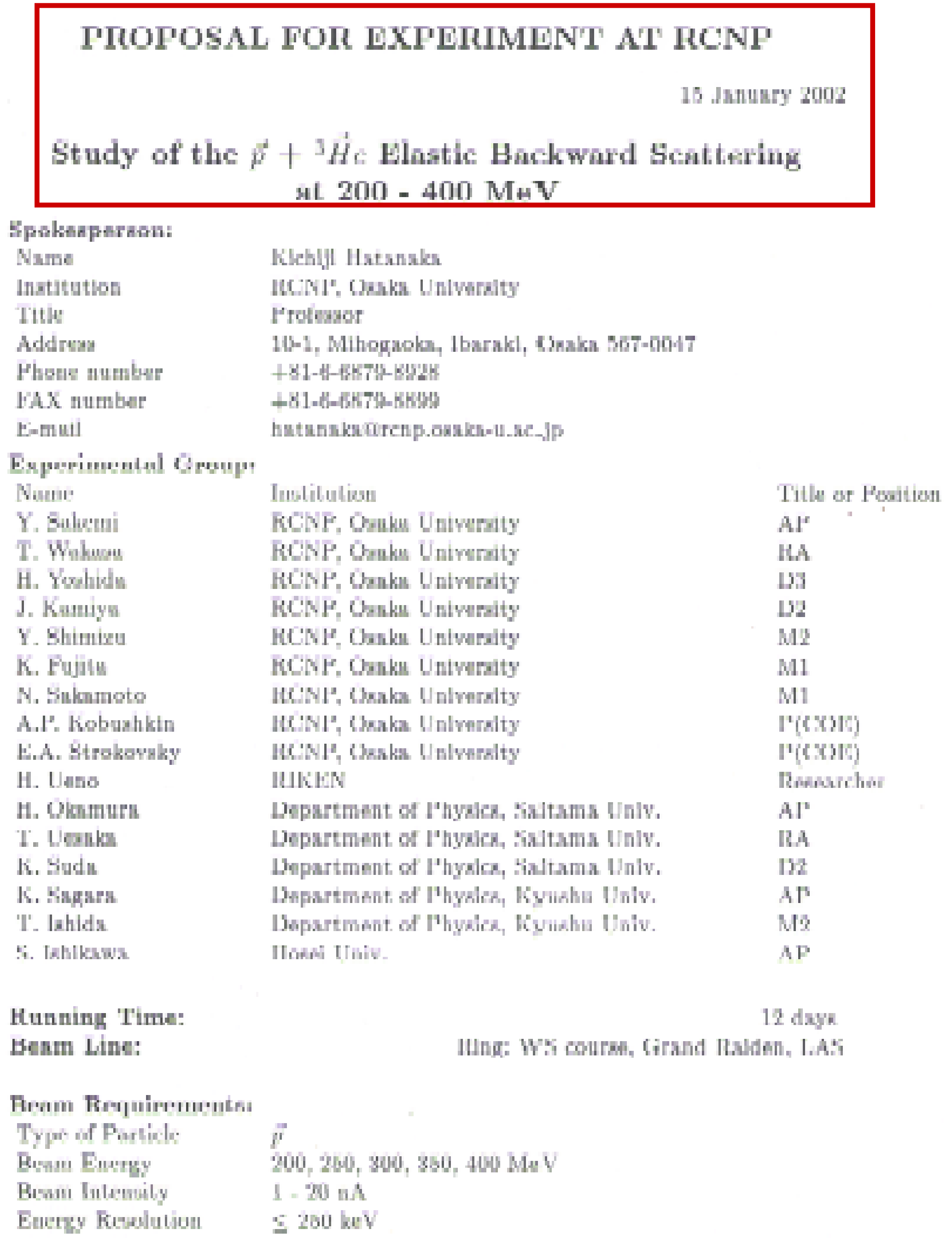


FIG. 6: Polarization transfer κ_d from ^{3}He to d for the Paris (solid) and CD-Bonn (dashed) potentials.



PROPOSAL FOR EXPERIMENT AT RCNP

15 January 2002

Study of the $\vec{p}$ + $^3\vec{He}$ Elastic Backward Scattering at 200 - 400 MeV

Spokesperson:

Name	Kichiji Hatanaka
Institution	RCNP, Osaka University
Title	Professor
Address	10-1, Mihogaoka, Ibaraki, Osaka 567-0047
Phone number	+81-6-6879-8928
FAX number	+81-6-6879-8899
E-mail	hatanaka@rcnp.osaka-u.ac.jp

Experimental Group:

Name	Institution	Title or Position
Y. Sakemi	RCNP, Osaka University	AP
T. Wakasa	RCNP, Osaka University	RA
H. Yoshida	RCNP, Osaka University	D3
J. Kamiya	RCNP, Osaka University	D2
Y. Shimizu	RCNP, Osaka University	M2
K. Fujita	RCNP, Osaka University	M1
N. Sakamoto	RCNP, Osaka University	M1
A.P. Kobushkin	RCNP, Osaka University	P(COE)
E.A. Strokovsky	RCNP, Osaka University	P(COE)
H. Ueno	RIKEN	Researcher
H. Okamura	Department of Physics, Saitama Univ.	AP
T. Uesaka	Department of Physics, Saitama Univ.	RA
K. Suda	Department of Physics, Saitama Univ.	D2
K. Sagara	Department of Physics, Kyushu Univ.	AP
T. Ishida	Department of Physics, Kyushu Univ.	M2
S. Ishikawa	Hosei Univ.	AP

Running Time: 12 days

Beam Line: Ring: WS course, Grand Raiden, LAS

Beam Requirements:

Type of Particle	$\vec{p}$
Beam Energy	200, 250, 300, 350, 400 MeV
Beam Intensity	1 - 20 nA
Energy Resolution	$\leq$ 250 keV

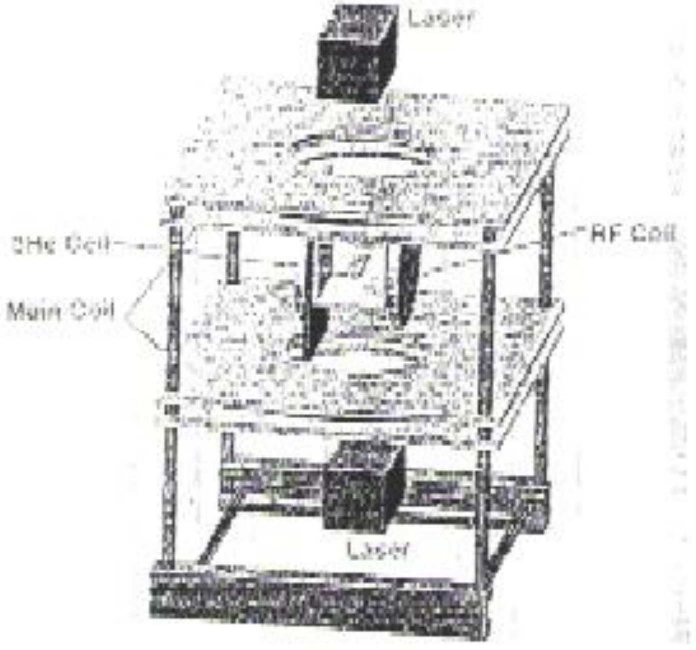


Fig. 7. Schematic layout of the polarized ^{3}He target system [34].

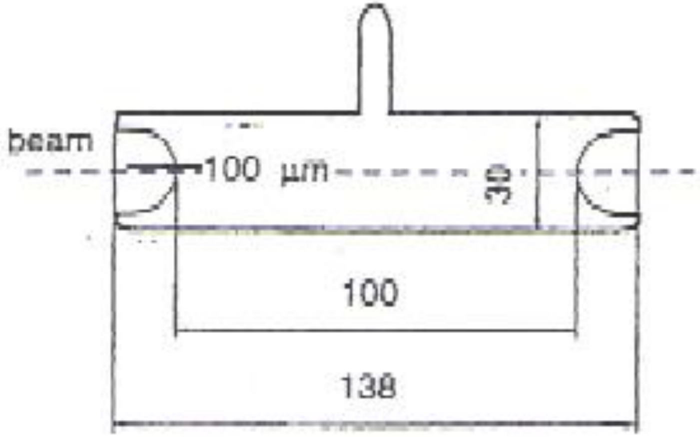


Fig. 8. The target cell [36]. Thickness of the entrance and exit windows is 100 µm.

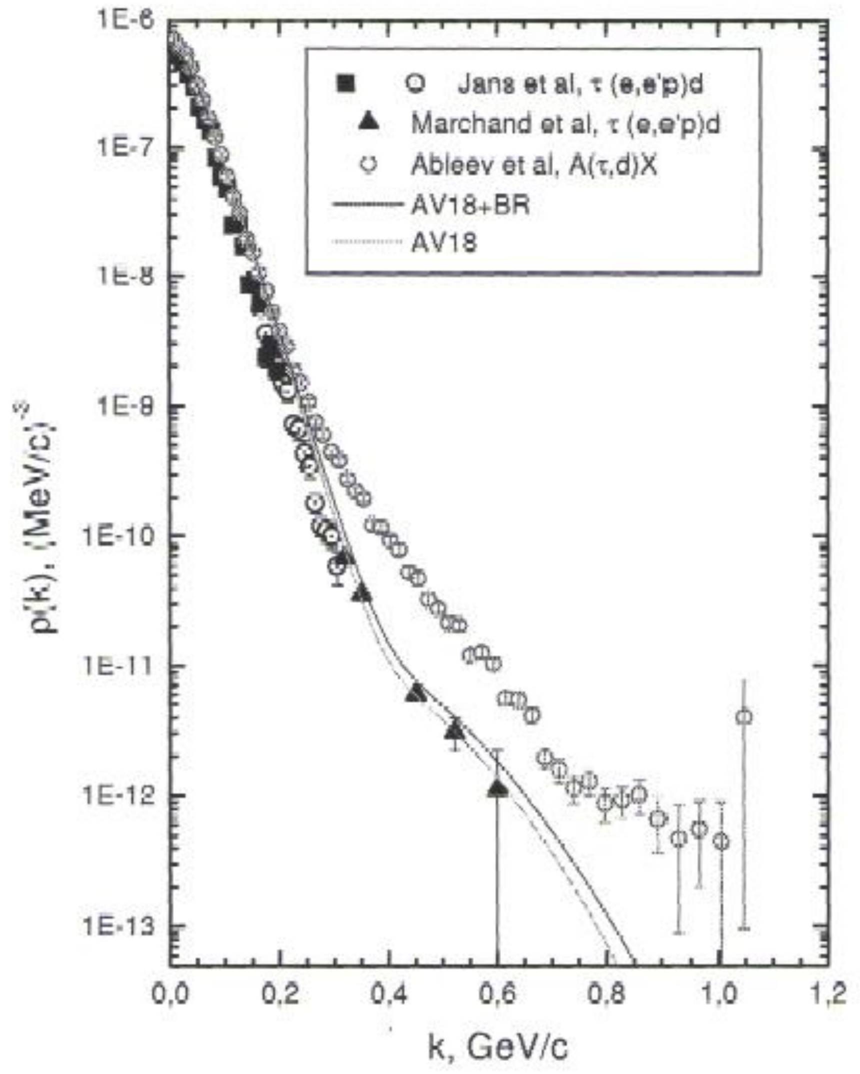


Fig. 3. Empirical momentum distribution of the deuterons in ^{3}He extracted from exclusive electrodisintegration; data are taken from refs. [11]. They are also compared with the effective momentum distrubution extracted from inclusive ^{12}C(^{3}He, d)X breakup from ref.[8]. The lines are the same as in Fig.1.

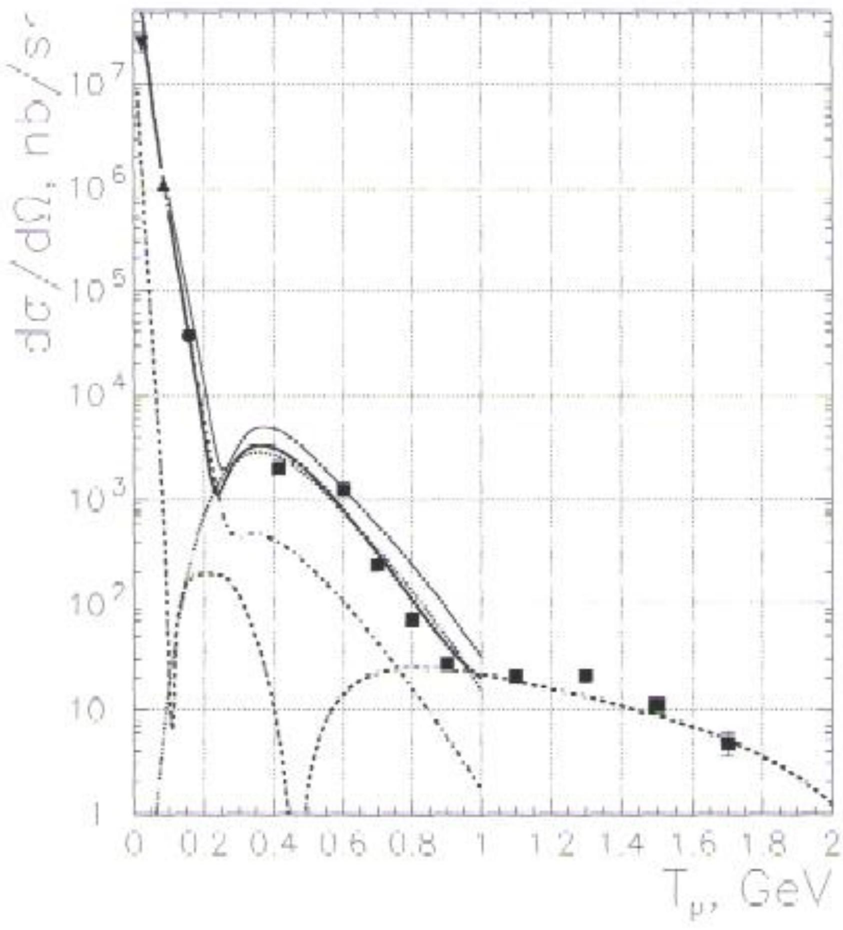


Fig. 5. Differential elastic cross section at $\theta_{cm} = 180°$. The bold solid line represents ODE+DIR+PI for the wave function with Argonne V18 potential. The dot-dashed and dashed lines represent the ODE and DIR mechanisms, respectively. The dotted line is for the PI mechanism. The thin solid line represents ODE+DIR+PI for the wave function with Urbana potential. Data are from: square — [17], "down" triangle — [30], "up" triangle — [31] and circle — [32]. Data [30–32] were extrapolated to $\theta_{cm} = 180°$ by us.

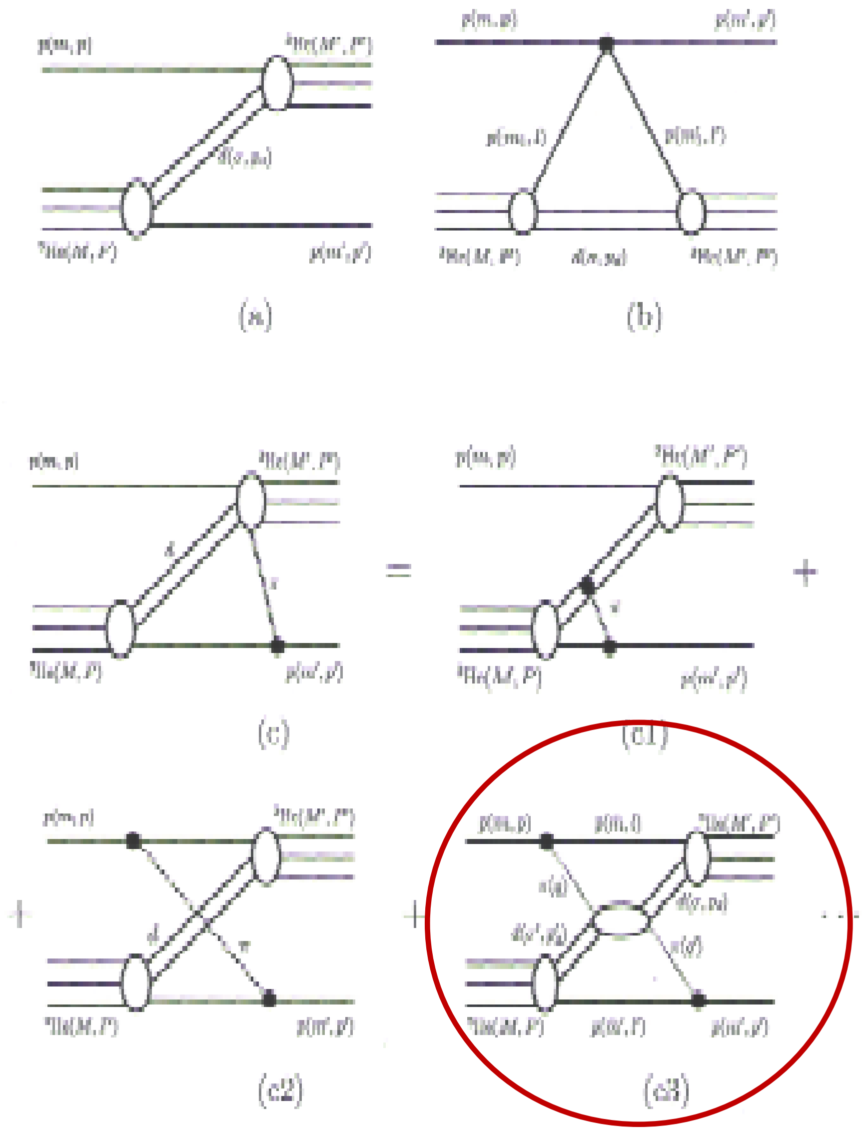


Fig. 4. Reaction mechanisms of the p³He elastic backward scattering: one deuteron exchange (ODE, (a)), direct mechanism (DIR, (b)) and the "triangle" diagram, (c). The diagrams (c1), (c2) and (c3) are subprocesses contributing to the triangle diagram.

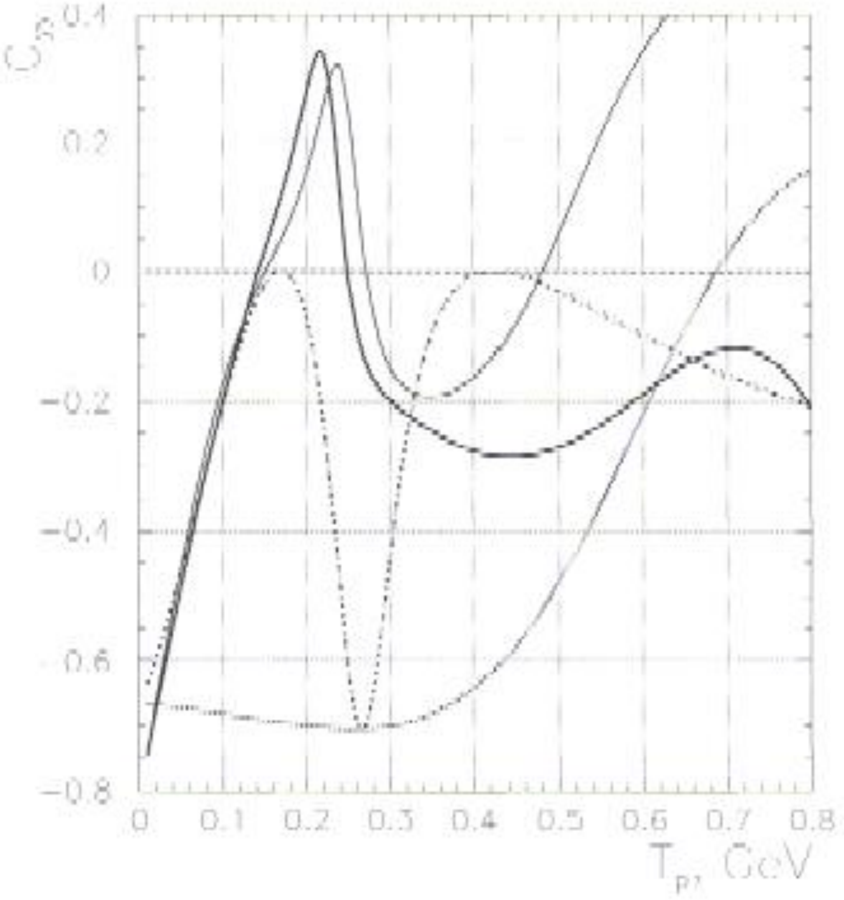
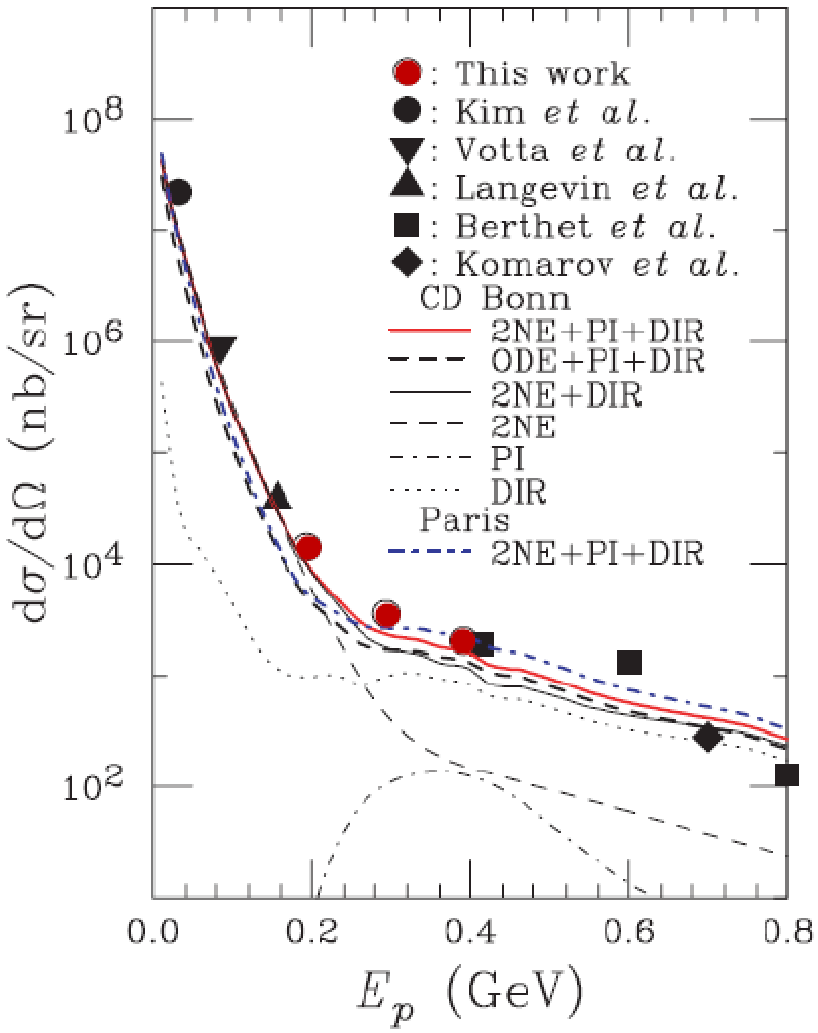
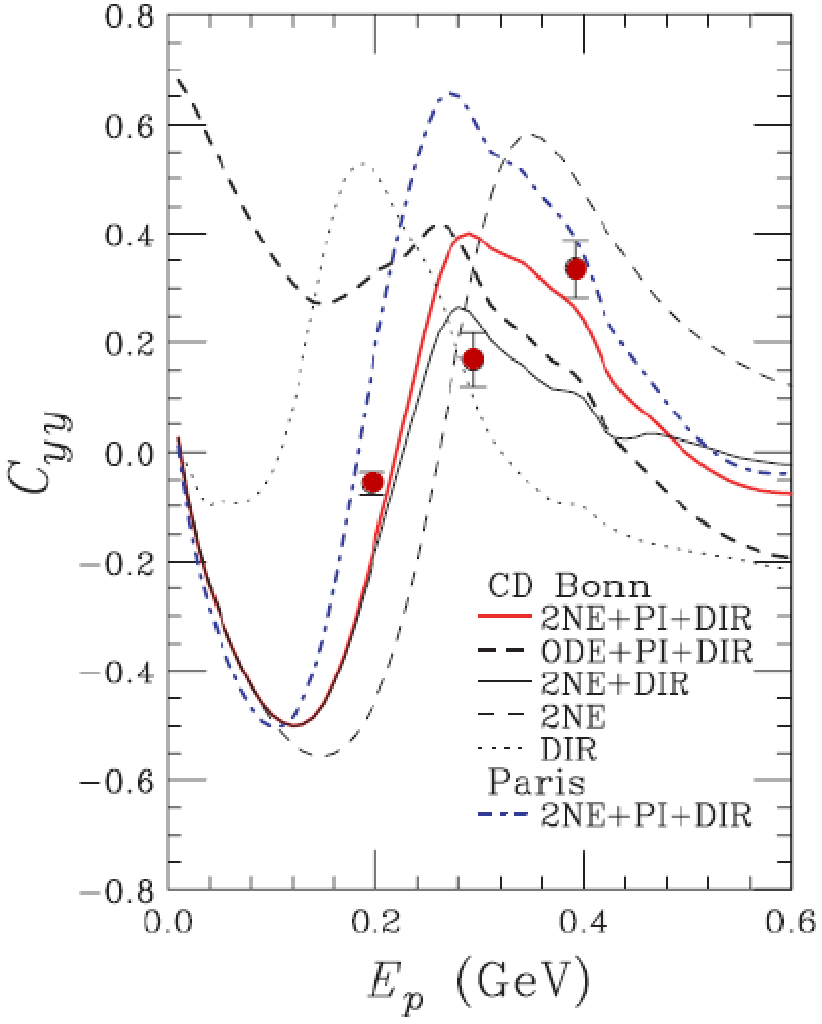


Fig. 6. Predictions of the model for the polarization correlation C_{yy}. The lines are the same as at Fig. 5.

Spin correlation parameter C_{yy} of $p+{}^3$He elastic backward scattering

PHYSICAL REVIEW C **76**, 044003 (2007) Y. SHIMIZU *et al.*





E.A.Strokovsky, DSPIN-13, Dubna, Oct. 2013

Об эффективных 3N, 4N и т.д. силах…

«ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА»
1993, ТОМ 24, ВЫП.3

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ДЕЛЬТА-ИЗОБАРНЫЕ ВОЗБУЖДЕНИЯ АТОМНЫХ ЯДЕР В ЗАРЯДОВО-ОБМЕННЫХ РЕАКЦИЯХ

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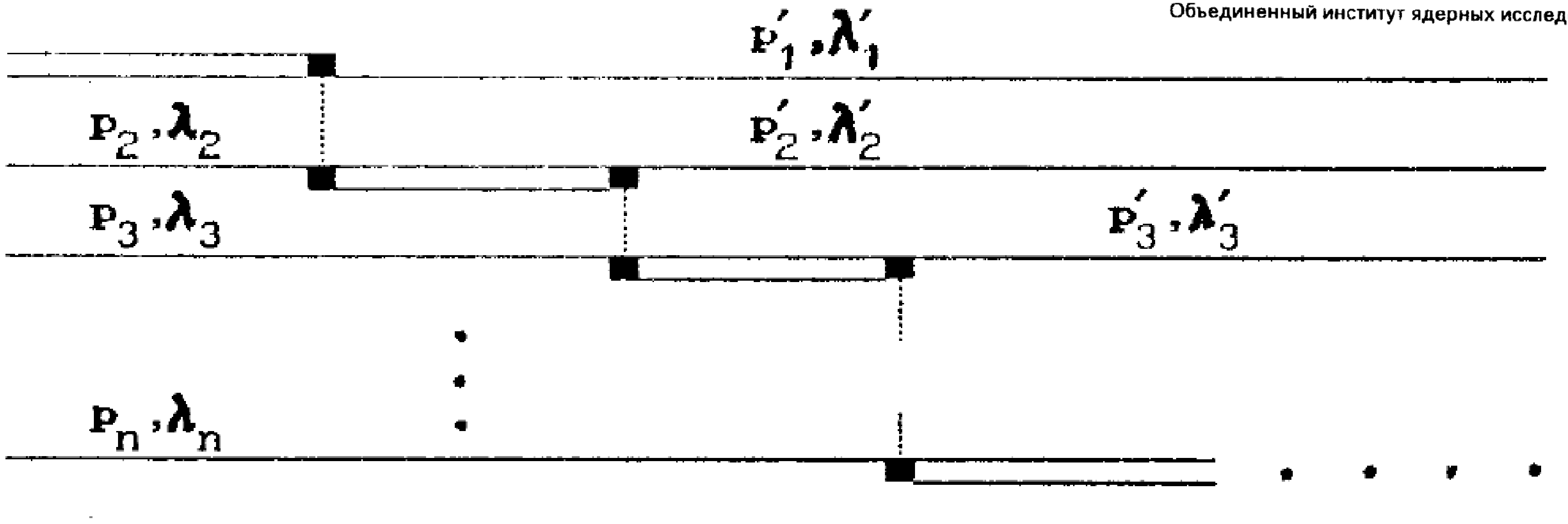

Рис.1. Типичная диаграмма, соответствующая распространению пиона в ядре согласно процессу, описанному в тексте