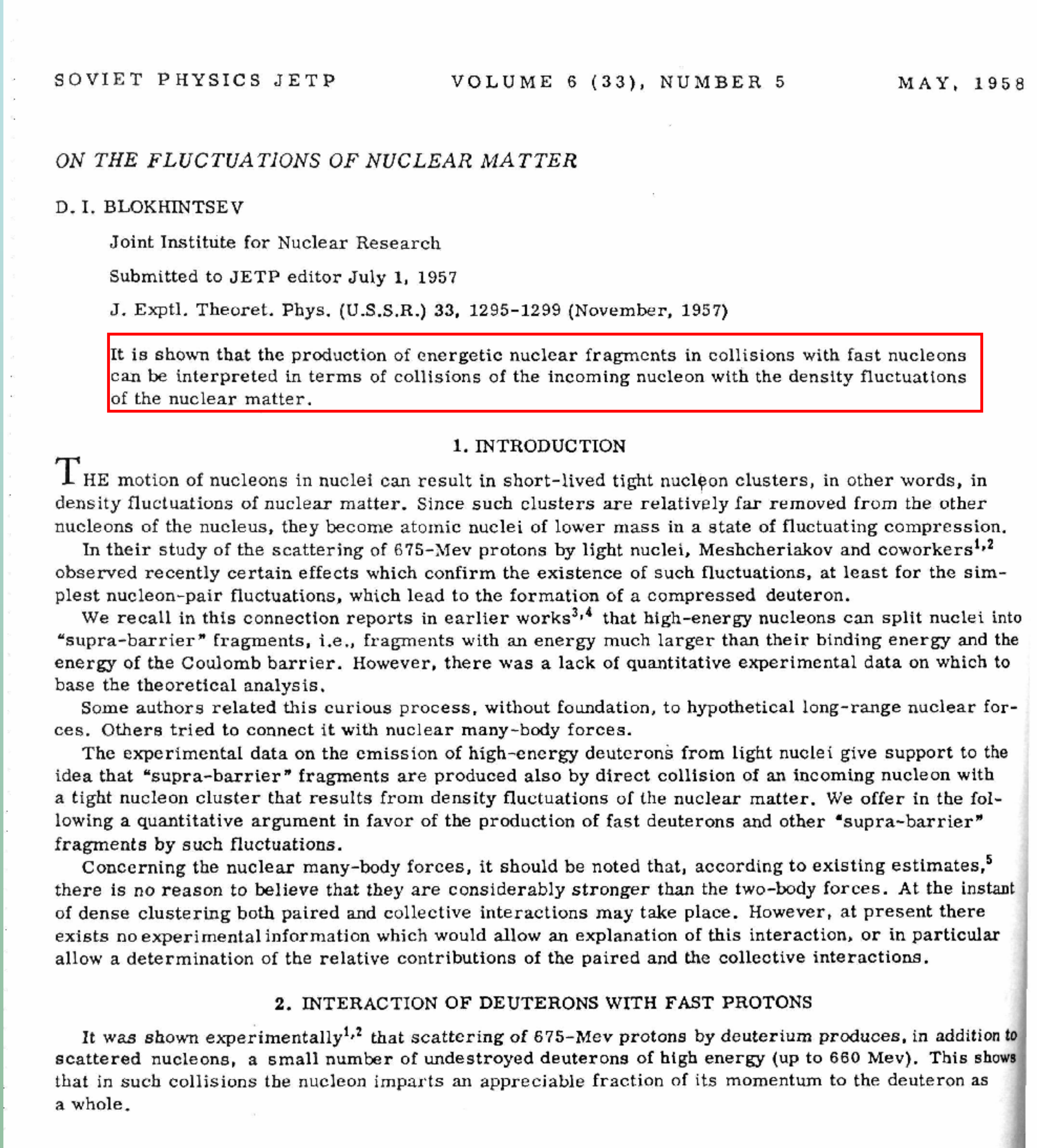
"Prospects for Constituent(Color) Quark Condensate of nuclear matter study at nuclotron and …"

Shimanskiy S. (VBLHEP,JINR)

What is Constituent(Color) Quark Condensate Of Nuclear Matter?

CQC

100 Blokhintsev in 2008



SOVIET PHYSICS JETP VOLUME 6 (33), NUMBER 5 MAY, 1958

ON THE FLUCTUATIONS OF NUCLEAR MATTER

D. I. BLOKHINTSEV

Joint Institute for Nuclear Research

Submitted to JETP editor July 1, 1957

J. Exptl. Theoret. Phys. (U.S.S.R.) 33, 1295-1299 (November, 1957)

It is shown that the production of energetic nuclear fragments in collisions with fast nucleons can be interpreted in terms of collisions of the incoming nucleon with the density fluctuations of the nuclear matter.

1. INTRODUCTION

THE motion of nucleons in nuclei can result in short-lived tight nucleon clusters, in other words, in density fluctuations of nuclear matter. Since such clusters are relatively far removed from the other nucleons of the nucleus, they become atomic nuclei of lower mass in a state of fluctuating compression.

In their study of the scattering of 675-Mev protons by light nuclei, Meshcheriakov and coworkers[1,2] observed recently certain effects which confirm the existence of such fluctuations, at least for the simplest nucleon-pair fluctuations, which lead to the formation of a compressed deuteron.

We recall in this connection reports in earlier works[3,4] that high-energy nucleons can split nuclei into "supra-barrier" fragments, i.e., fragments with an energy much larger than their binding energy and the energy of the Coulomb barrier. However, there was a lack of quantitative experimental data on which to base the theoretical analysis.

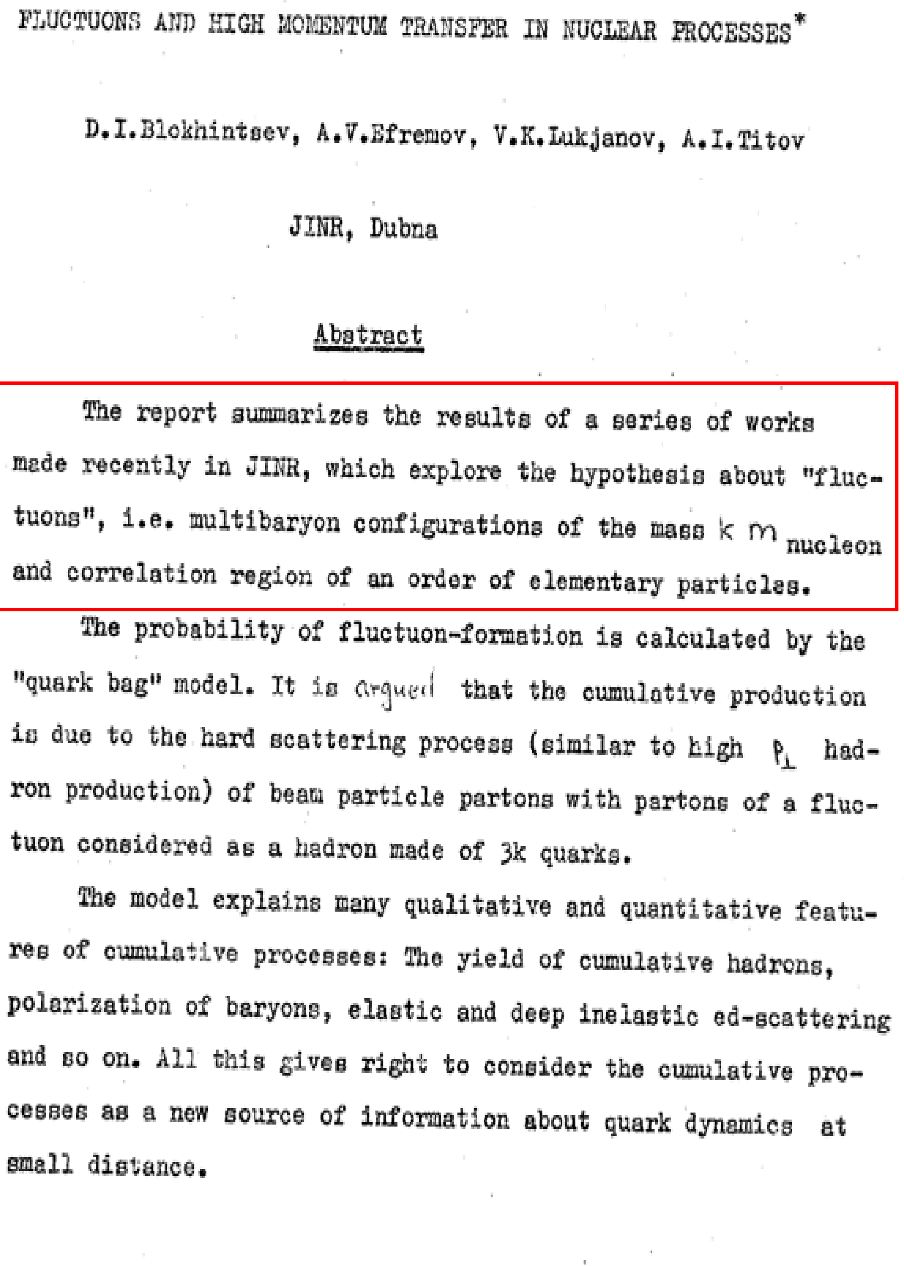
Some authors related this curious process, without foundation, to hypothetical long-range nuclear forces. Others tried to connect it with nuclear many-body forces.

The experimental data on the emission of high-energy deuterons from light nuclei give support to the idea that "supra-barrier" fragments are produced also by direct collision of an incoming nucleon with a tight nucleon cluster that results from density fluctuations of the nuclear matter. We offer in the following a quantitative argument in favor of the production of fast deuterons and other "supra-barrier" fragments by such fluctuations.

Concerning the nuclear many-body forces, it should be noted that, according to existing estimates,[5] there is no reason to believe that they are considerably stronger than the two-body forces. At the instant of dense clustering both paired and collective interactions may take place. However, at present there exists no experimental information which would allow an explanation of this interaction, or in particular allow a determination of the relative contributions of the paired and the collective interactions.

2. INTERACTION OF DEUTERONS WITH FAST PROTONS

It was shown experimentally[1,2] that scattering of 675-Mev protons by deuterium produces, in addition to scattered nucleons, a small number of undestroyed deuterons of high energy (up to 660 Mev). This shows that in such collisions the nucleon imparts an appreciable fraction of its momentum to the deuteron as a whole.



FLUCTUONS AND HIGH MOMENTUM TRANSFER IN NUCLEAR PROCESSES*

D.I.Blokhintsev, A.V.Efremov, V.K.Lukjanov, A.I.Titov

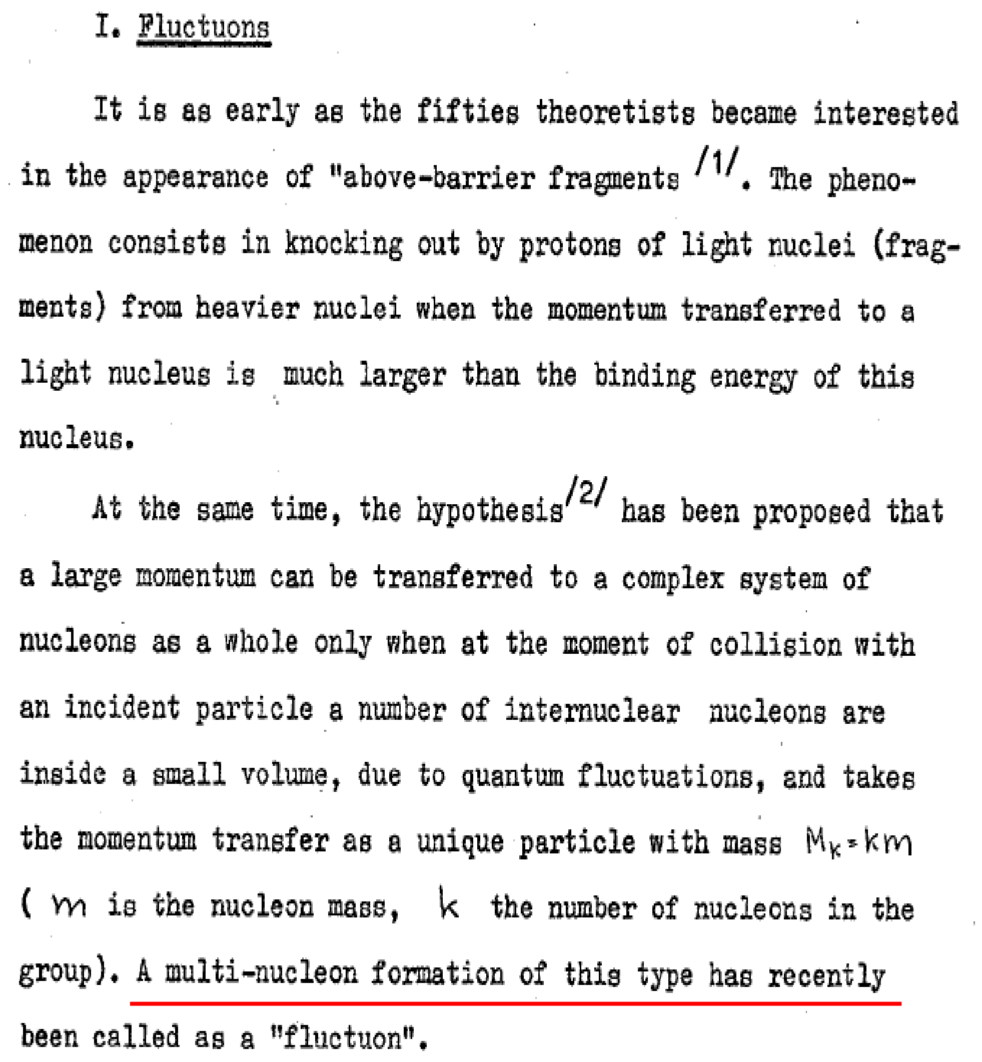
JINR, Dubna

Abstract

The report summarizes the results of a series of works made recently in JINR, which explore the hypothesis about "fluctuons", i.e. multibaryon configurations of the mass $k\,m_{\text{nucleon}}$ and correlation region of an order of elementary particles.

The probability of fluctuon-formation is calculated by the "quark bag" model. It is argued that the cumulative production is due to the hard scattering process (similar to high $p_\perp$ hadron production) of beam particle partons with partons of a fluctuon considered as a hadron made of 3k quarks.

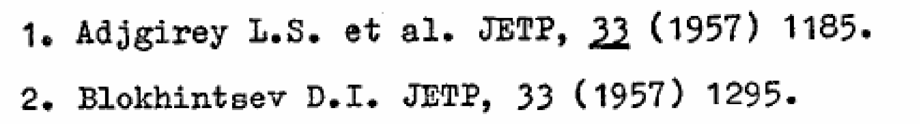
The model explains many qualitative and quantitative features of cumulative processes: The yield of cumulative hadrons, polarization of baryons, elastic and deep inelastic ed-scattering and so on. All this gives right to consider the cumulative processes as a new source of information about quark dynamics at small distance.



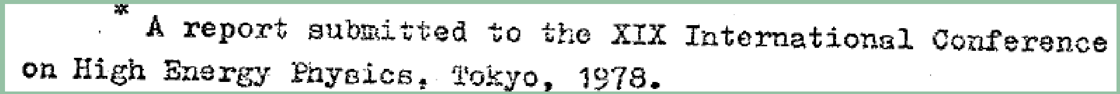
I. Fluctuons

It is as early as the fifties theoretists became interested in the appearance of "above-barrier fragments /1/. The phenomenon consists in knocking out by protons of light nuclei (fragments) from heavier nuclei when the momentum transferred to a light nucleus is much larger than the binding energy of this nucleus.

At the same time, the hypothesis /2/ has been proposed that a large momentum can be transferred to a complex system of nucleons as a whole only when at the moment of collision with an incident particle a number of internuclear nucleons are inside a small volume, due to quantum fluctuations, and takes the momentum transfer as a unique particle with mass $M_k = km$ (m is the nucleon mass, k the number of nucleons in the group). A multi-nucleon formation of this type has recently been called as a "fluctuon".



1. Adjgirey L.S. et al. JETP, 33 (1957) 1185.
2. Blokhintsev D.I. JETP, 33 (1957) 1295.



---

* A report submitted to the XIX International Conference on High Energy Physics, Tokyo, 1978.

How we can detect a nuclear matter with the high density?

The quantum theory saying: we need to study the processes with extremely high transfer momentum.

What we can see in processes with different probes ?

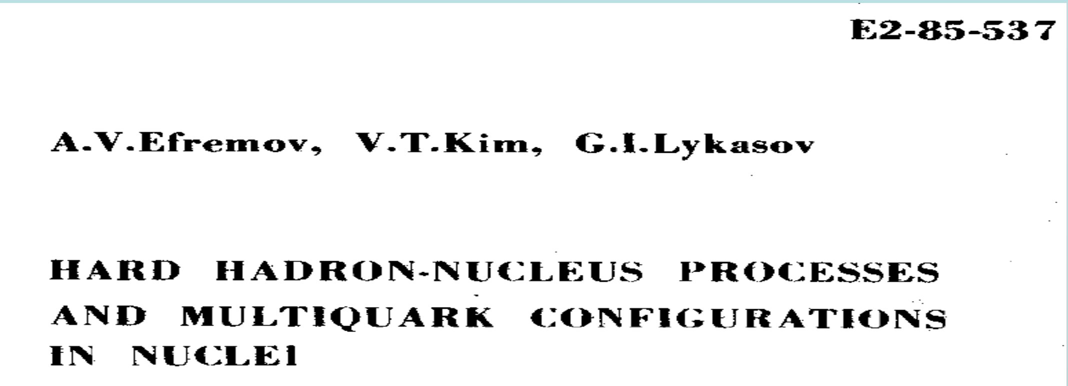
1. Hadrons and nuclei probes

2. Electromagnetic probes

Hadrons and nuclei probes

1. High p_T processes

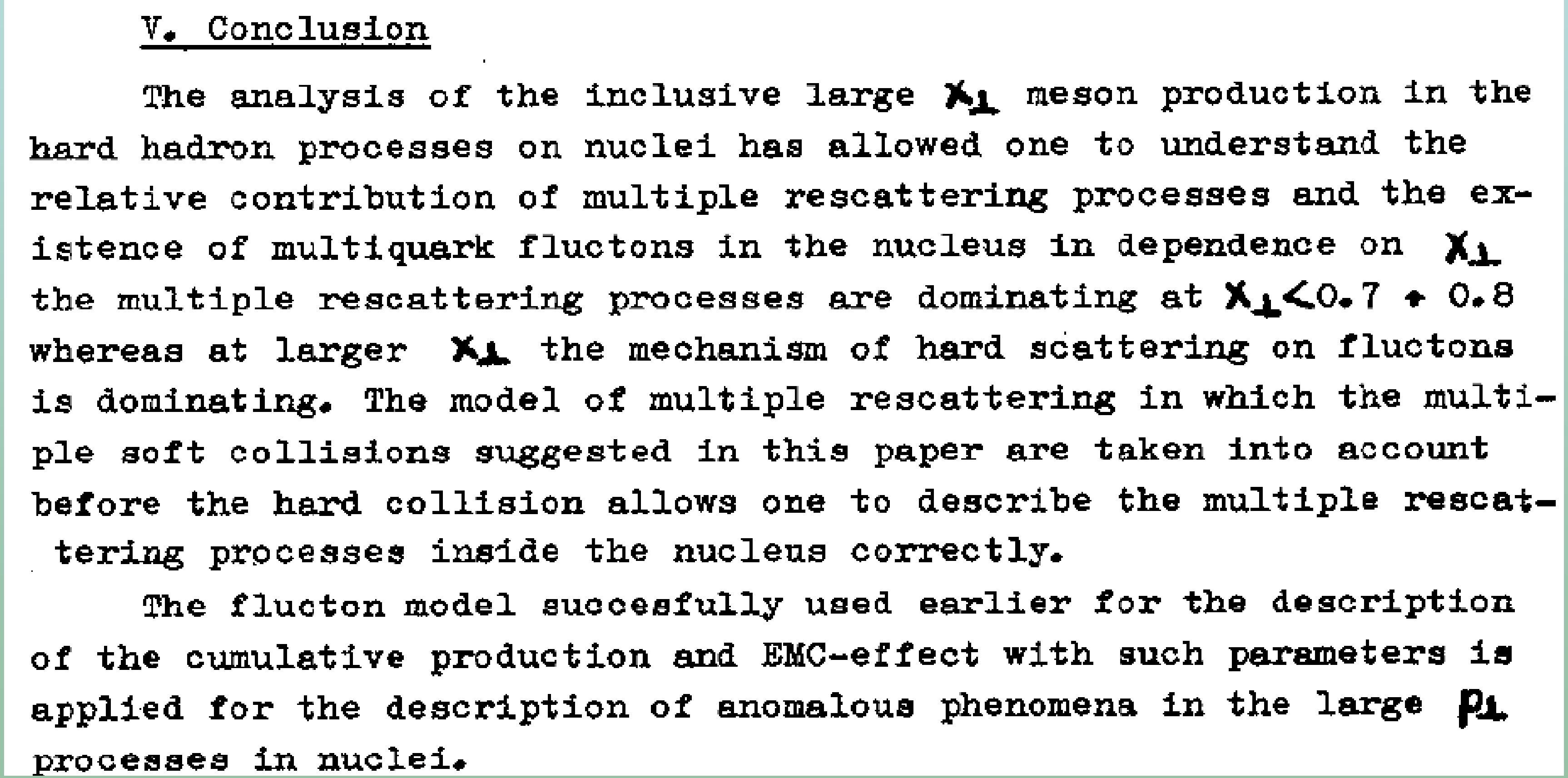
2. Cumulative and subthreshold processes



E2-85-537

A.V.Efremov, V.T.Kim, G.I.Lykasov

HARD HADRON-NUCLEUS PROCESSES AND MULTIQUARK CONFIGURATIONS IN NUCLEI



V. Conclusion

The analysis of the inclusive large $x_{\perp}$ meson production in the hard hadron processes on nuclei has allowed one to understand the relative contribution of multiple rescattering processes and the existence of multiquark fluctons in the nucleus in dependence on $x_{\perp}$ the multiple rescattering processes are dominating at $x_{\perp} < 0.7 \div 0.8$ whereas at larger $x_{\perp}$ the mechanism of hard scattering on fluctons is dominating. The model of multiple rescattering in which the multiple soft collisions suggested in this paper are taken into account before the hard collision allows one to describe the multiple rescattering processes inside the nucleus correctly.

The flucton model succesfully used earlier for the description of the cumulative production and EMC-effect with such parameters is applied for the description of anomalous phenomena in the large $p_{\perp}$ processes in nuclei.

In 1973 were published two artiles :

Matveev V.A., Muradyan R.M., Tavkhelidze A.N. Lett. Nuovo Cimento 7,719 (1973);

Brodsky S., Farrar G. Phys. Rev. Lett. 31,1153 (1973)

Predictions that for momentum $p_{beam} \geq 5$ GeV/c in any binary large-angle scattering ($\theta_{cm} > 40^o$) reaction at large momentum transfers $Q = \sqrt{-t}$:

$$A + B \to C + D$$

$$\left.\frac{d\sigma}{dt}\right._{A+B->C+D} \sim s^{-(n_A+n_B+n_C+n_D-2)} f\left(\frac{t}{s}\right)$$

where n_A, n_B, n_C and n_D the amounts of elementary constituents in A,B,C and D.

$s=(p_A+p_B)^2$ and $t=(p_A-p_C)^2$,

$$\left.\frac{d\sigma}{dt}\right._{pp->pp} \sim s^{-10} \quad \text{and} \quad \left.\frac{d\sigma}{dt}\right._{\pi p->\pi p} \sim s^{-8}$$

Pis'ma v ZhETF, vol. 81, iss. 7, pp. 387 − 390 © 2005 April 10

Indication of asymptotic scaling in the reactions $dd \to p^3$H, $dd \to n^3$He and $pd \to pd$

Yu. N. Uzikov[1)]
Joint Institute for Nuclear Research, LNP, 141980 Dubna, Moscow region, Russia

Submitted 11 January 2005
Resubmitted 28 February 2005

It is shown that the differential cross sections of the reactions $dd \to n^3$He and $dd \to p^3$H measured at c.m.s. scattering angle $\theta_{cm} = 60^\circ$ in the interval of the deuteron beam energy 0.5–1.2 GeV demonstrate the scaling behaviour, $d\sigma/dt \sim s^{-22}$, which follows from constituent quark counting rules. It is found also that the differential cross section of the elastic $dp \to dp$ scattering at $\theta_{cm} = 125$–135° follows the scaling regime $\sim s^{-16}$ at beam energies 0.5–5 GeV. These data are parameterized here using the Reggeon exchange.

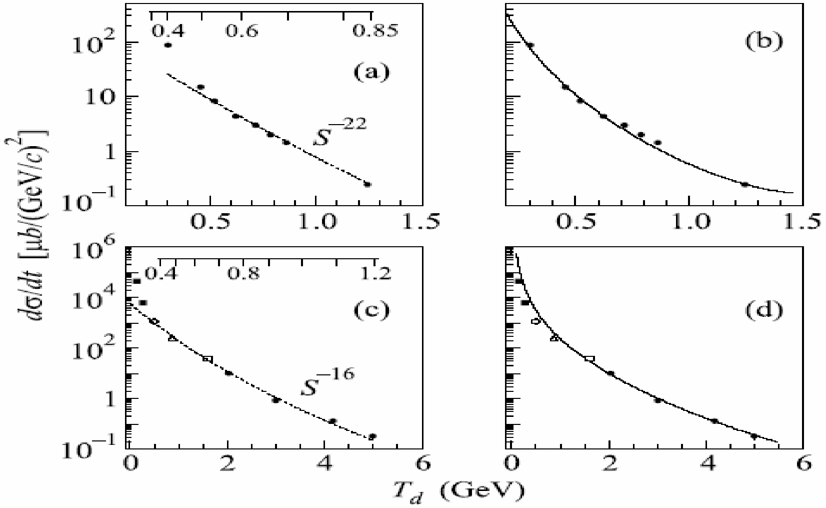
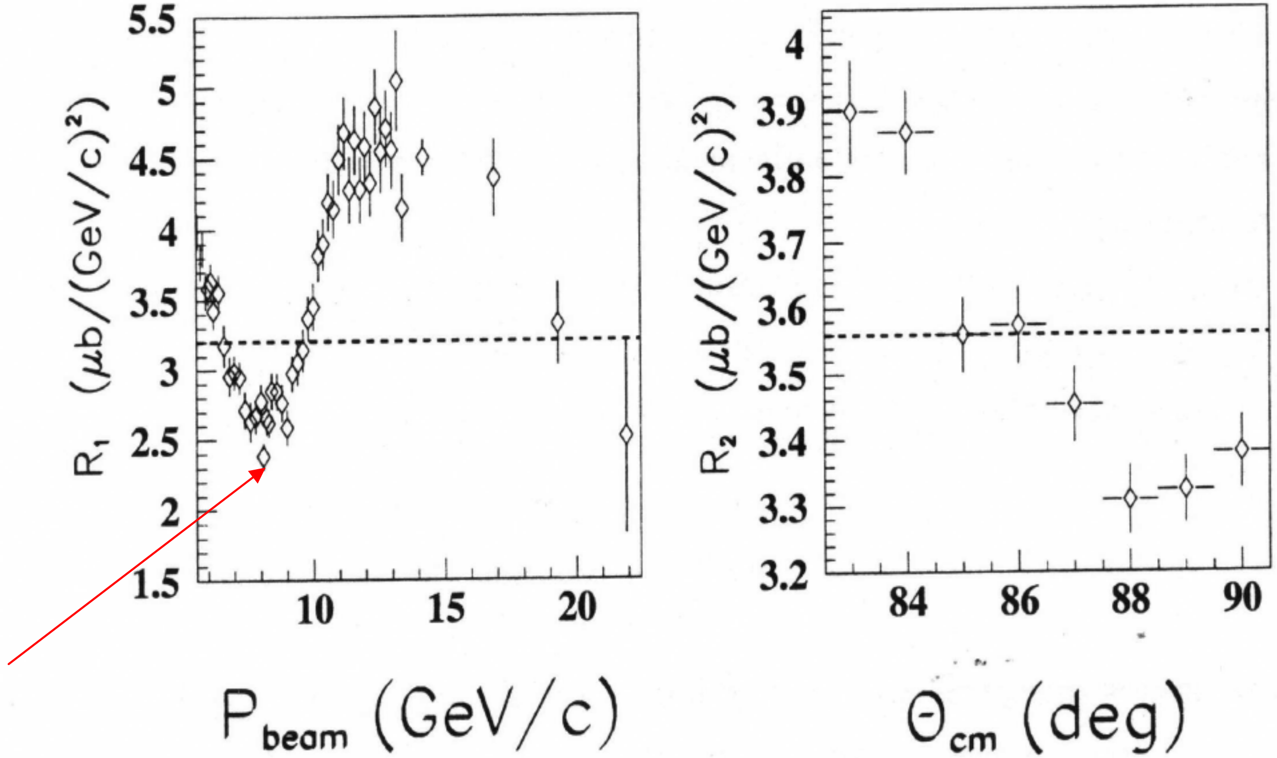


Fig.2. The differential cross section of the $dd \to n^3$He and $dd \to p^3$H reactions at $\theta_{cm} = 60^o$ (a), (b) and $dp \to dp$ at $\theta_{cm} = 127^o$ (c), (d) versus the deuteron beam kinetic energy. Experimental data in (a), (b) are taken from [20]. In (c), (d), the experimental data (black squares), (○), (△), (open square) and (●) are taken from [22 – 26], respectively. The dashed curves give the s^{-22} (a) and s^{-16} (c) behaviour. The full curves show the result of calculations using Regge formalism given by Eqs. (2), (3), (4) with the following parameters: (b) – $C_1 = 1.9\,\text{GeV}^2$, $R_1^2 = 0.2\,\text{GeV}^{-2}$, $C_2 = 3.5$, $R_2^2 = -0.1\,\text{GeV}^{-2}$; (d) – $C_1 = 7.2\,\text{GeV}^2$, $R_1^2 = 0.5\,\text{GeV}^{-2}$, $C_2 = 1.8$, $R_2^2 = -0.1\,\text{GeV}^{-2}$. The upper scales in (a) and (c) show the relative momentum q_{pn} (GeV/c) in the deuteron for the ONE mechanism

Mardor's thesis, 1997



8 GeV/c

Figure 1.2: Scaled $pp \rightarrow pp$ differential cross sections. The dashed lines represent perfect scaling. Their vertical position is arbitrary. **Left** - $R_1 = \left(\left(\frac{s}{s_0}\right)^{10} \frac{d\sigma}{dt}(pp)\right)^{-1}$ ($s_0 = 13\ GeV^2$) at $\theta_{cm} = 90^0$ versus incoming momentum. Data are from Ref. [19]. **Right** - $R_2 = (1 - \cos^2\theta_{cm})^{4\gamma} \frac{d\sigma}{dt}(pp)$ ($\gamma = 1.6$) at $p_{lab} = 5.9$ GeV/c versus θ_{cm}. Data are from Ref. [17].

PHYSICAL REVIEW D VOLUME 23, NUMBER 3 1 FEBRUARY 1981

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

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

J. R. O'Fallon
Argonne Universities Association, Argonne, Illinois 60439

D. G. Crabb, R. C. Fernow,[*] P. H. Hansen,[†] A. D. Krisch, A. J. Salthouse,[‡] B. Sandler,[§] T. Shima, and K. M. Terwilliger
Randall Laboratory of Physics, The University of Michigan, Ann Arbor, Michigan 48109

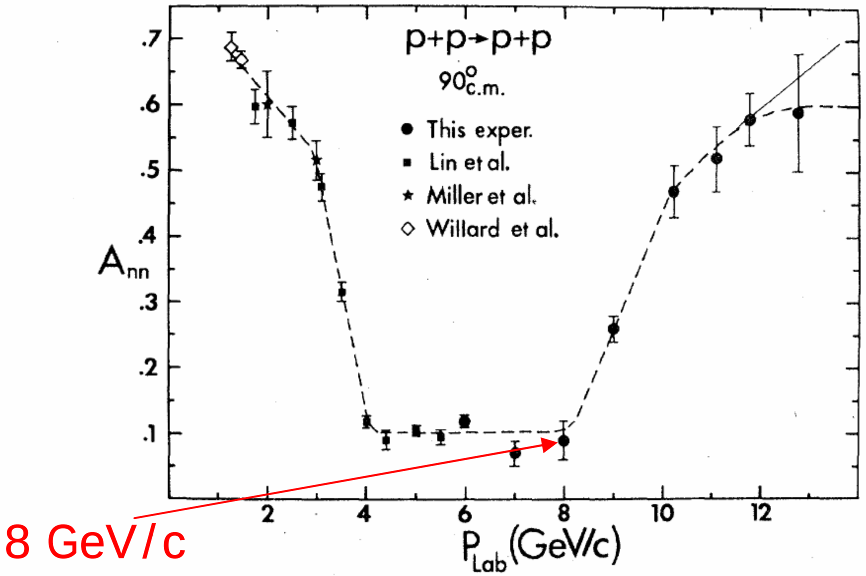
N. L. Karmakar
University of Kiel, Kiel, Germany

S. L. Linn[‖] and A. Perlmutter
Department of Physics and Center for Theoretical Studies, The University of Miami, Coral Gables, Florida 33124

P. Kyberd
Nuclear Physics Laboratory, Oxford University, Oxford, England

(Received 31 March 1980)

The energy dependence of the spin-parallel and spin-antiparallel cross sections for $p_\uparrow + p_\uparrow \to p + p$ at $90°_{\text{c.m.}}$ was measured for beam momenta between 6 and 12.75 GeV/c. The ratio $(d\sigma/dt)_{\text{parallel}}/(d\sigma/dt)_{\text{antiparallel}}$ at 90° is about 1.2 up to 8 GeV/c and then increases rapidly to a value of almost 4 near 11 GeV/c. Our data indicate that this ratio may depend only on the variable $P_\perp^2$, and suggests that the ratio may reach a limiting value of about 4 for large $P_\perp^2$.



8 GeV/c

FIG. 2. Plot of the spin-spin correlation parameter A_{nn} for $p+p \to p+p$ at $90°_{\text{c.m.}}$ as a function of incident beam momentum. The dashed and solid lines are hand-drawn possible fits.

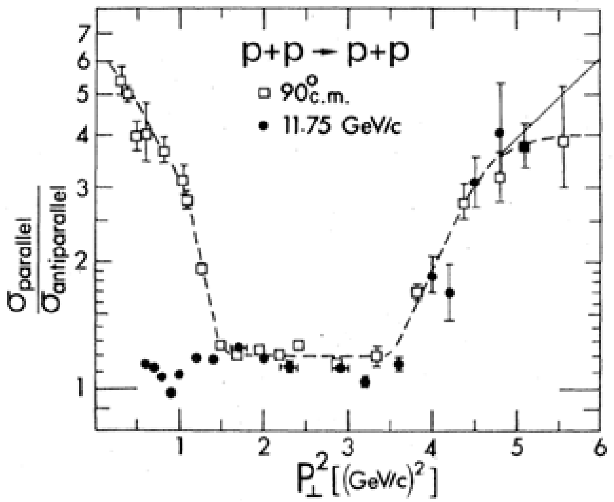
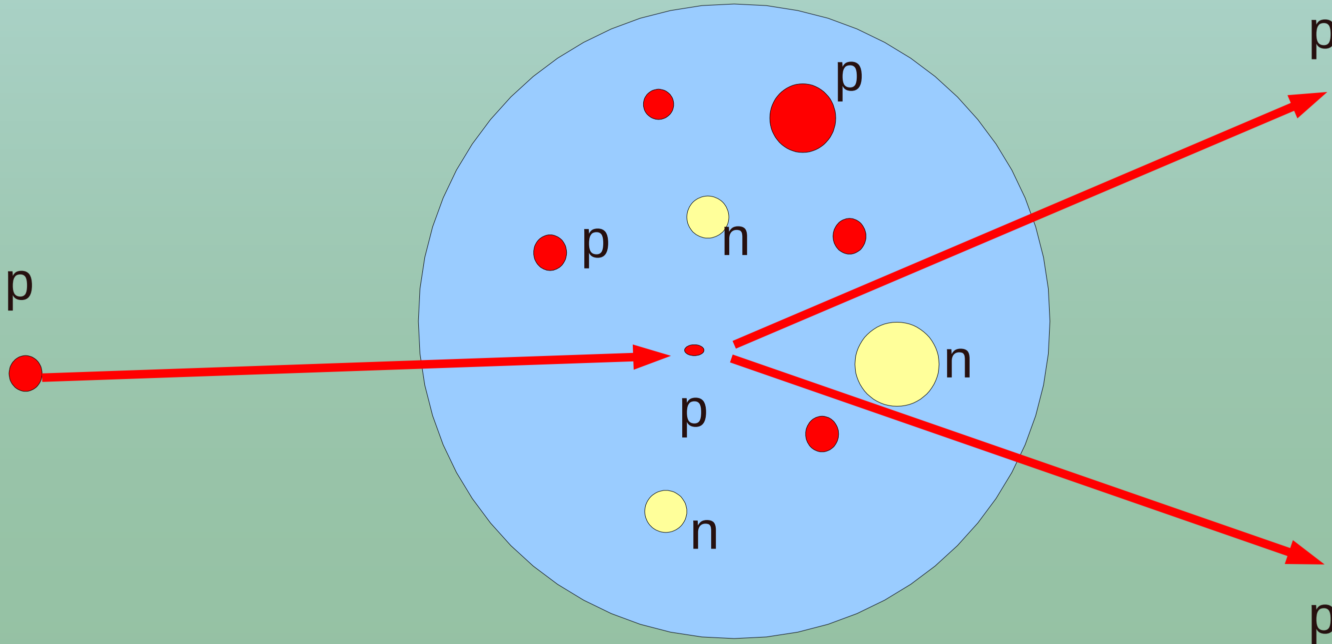


FIG. 3. Plot of the ratio of the spin-parallel to spin-antiparallel differential cross sections, as a function of $P_\perp^2$, for p-p elastic scattering. The squares are the fixed-angle data at $90°_{\text{c.m.}}$, with the incident energy varied. The circles are data (Refs. 5, 11) with the momentum held fixed at 11.75 GeV/c while the scattering angle is varied. The dashed and solid lines are hand-drawn possible fits to the $90°_{\text{c.m.}}$ data.

Color(nuclear) transparency in 90^0 c.m. quasielastic $A(p,2p)$ reactions

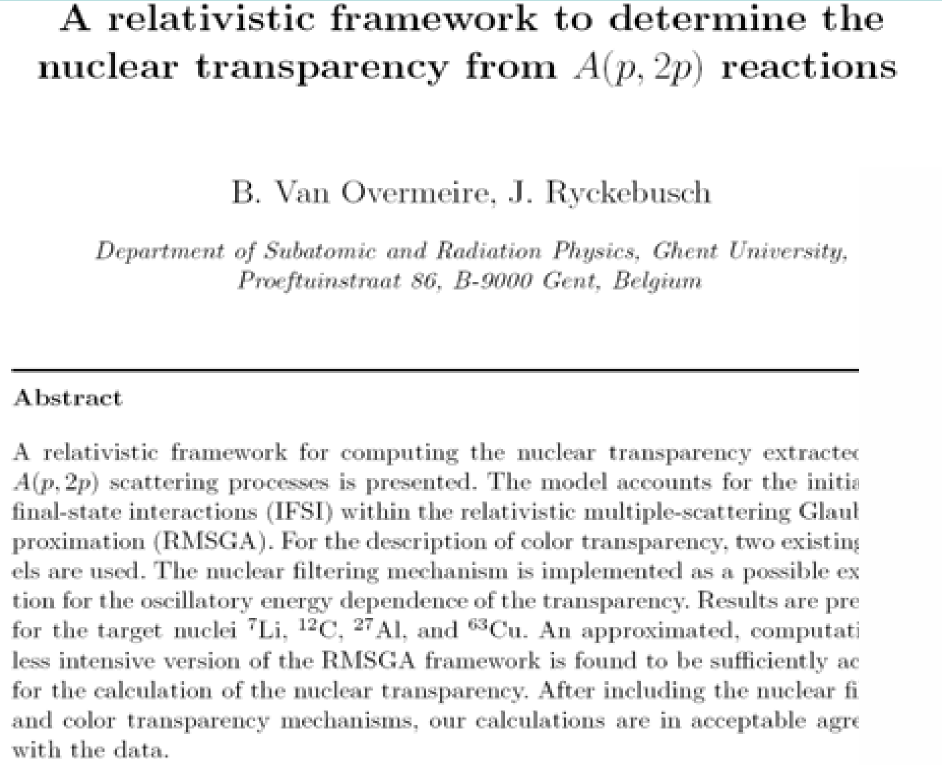
The incident momenta varied from 5.9 to 14.4 GeV/c, corresponding to $4.8 < Q^2 < 12.7\ (\mathrm{GeV}/c)^2$.

$$T = \frac{\frac{d\sigma}{dt}(p + "p" \rightarrow p + p)}{Z\frac{d\sigma}{dt}(p + p \rightarrow p + p)}$$



Shimanskiy S.S.

nucl-th/0608040 v2 21 Nov 2006



A relativistic framework to determine the nuclear transparency from $A(p,2p)$ reactions

B. Van Overmeire, J. Ryckebusch

Department of Subatomic and Radiation Physics, Ghent University,
Proeftuinstraat 86, B-9000 Gent, Belgium

Abstract

A relativistic framework for computing the nuclear transparency extracted
$A(p,2p)$ scattering processes is presented. The model accounts for the initia
final-state interactions (IFSI) within the relativistic multiple-scattering Glaul
proximation (RMSGA). For the description of color transparency, two existing
els are used. The nuclear filtering mechanism is implemented as a possible ex
tion for the oscillatory energy dependence of the transparency. Results are pre
for the target nuclei ^{7}Li, ^{12}C, ^{27}Al, and ^{63}Cu. An approximated, computati
less intensive version of the RMSGA framework is found to be sufficiently ac
for the calculation of the nuclear transparency. After including the nuclear fi
and color transparency mechanisms, our calculations are in acceptable agre
with the data.

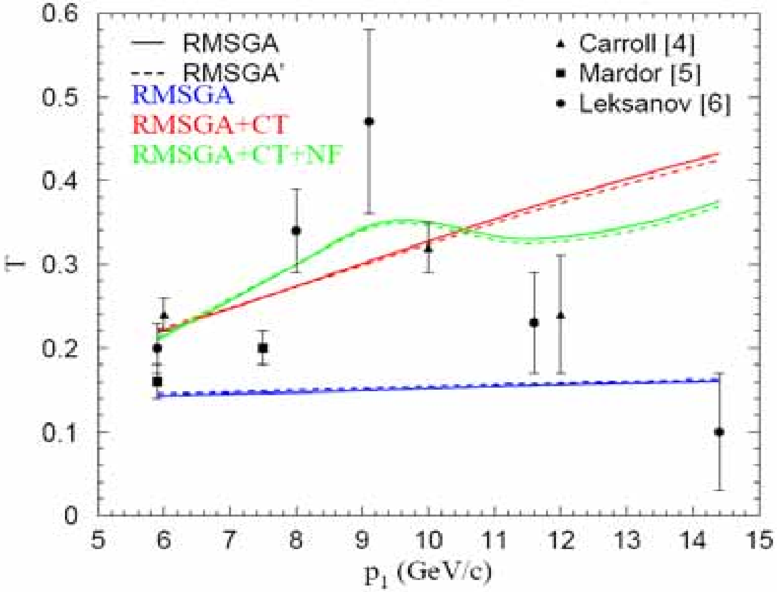
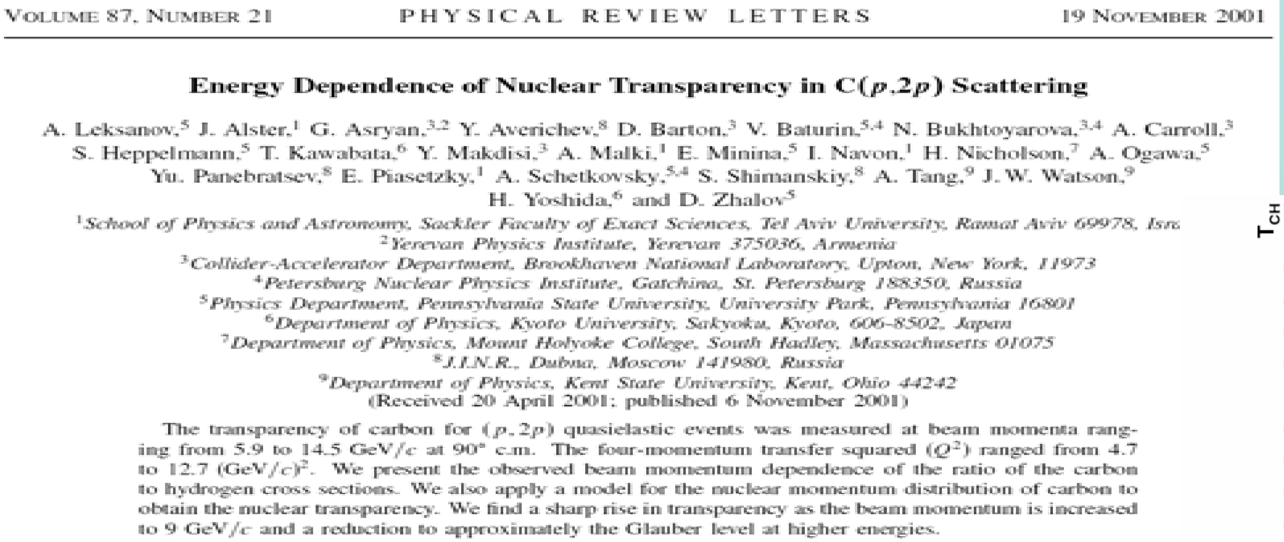


Fig. 1. The nuclear transparency for the ^{12}C$(p,2p)$ reaction as a function
the incoming lab momentum p_1. The full RMSGA (solid lines) are compared
the RMSGA$'$ (dashed lines) results. The different curves represent the RMSG
RMSGA+CT and RMSGA+CT+NF calculations. The CT effects are calculat
in the FLFS model [21] with $\Delta M^2 = 0.7$ (GeV/c^2)^2 and the results including t
mechanism of NF are obtained using the positive sign of $\phi(s) + \delta_1$. Data are fro
Refs. [4,5,6].



VOLUME 87, NUMBER 21 PHYSICAL REVIEW LETTERS 19 NOVEMBER 2001

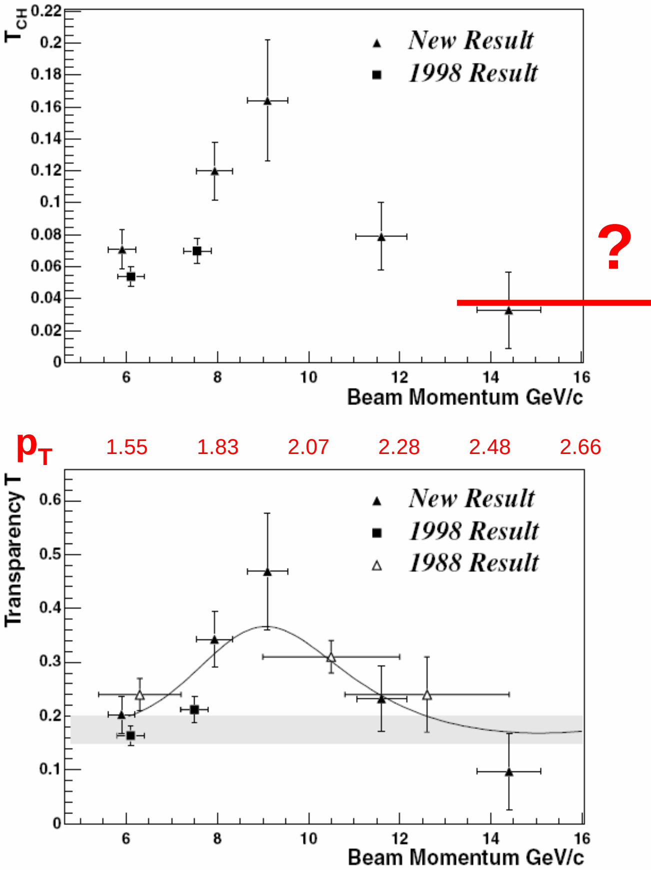
Energy Dependence of Nuclear Transparency in C(p,2p) Scattering

A. Leksanov,[5] J. Alster,[1] G. Asryan,[3,2] Y. Averichev,[8] D. Barton,[3] V. Baturin,[5,4] N. Bukhtoyarova,[3,4] A. Carroll,[3]
S. Heppelmann,[5] T. Kawabata,[6] Y. Makdisi,[3] A. Malki,[1] E. Minina,[5] I. Navon,[1] H. Nicholson,[7] A. Ogawa,[5]
Yu. Panebratsev,[8] E. Piasetzky,[1] A. Schetkovsky,[5,4] S. Shimanskiy,[8] A. Tang,[9] J. W. Watson,[9]
H. Yoshida,[6] and D. Zhalov[5]

[1]*School of Physics and Astronomy, Sackler Faculty of Exact Sciences, Tel Aviv University, Ramat Aviv 69978, Isr*
[2]*Yerevan Physics Institute, Yerevan 375036, Armenia*
[3]*Collider-Accelerator Department, Brookhaven National Laboratory, Upton, New York, 11973*
[4]*Petersburg Nuclear Physics Institute, Gatchina, St. Petersburg 188350, Russia*
[5]*Physics Department, Pennsylvania State University, University Park, Pennsylvania 16801*
[6]*Department of Physics, Kyoto University, Sakyoku, Kyoto, 606-8502, Japan*
[7]*Department of Physics, Mount Holyoke College, South Hadley, Massachusetts 01075*
[8]*J.I.N.R., Dubna, Moscow 141980, Russia*
[9]*Department of Physics, Kent State University, Kent, Ohio 44242*

(Received 20 April 2001; published 6 November 2001)

The transparency of carbon for (p,2p) quasielastic events was measured at beam momenta ranging from 5.9 to 14.5 GeV/c at 90° c.m. The four-momentum transfer squared (Q^2) ranged from 4.7 to 12.7 (GeV/c)^2. We present the observed beam momentum dependence of the ratio of the carbon to hydrogen cross sections. We also apply a model for the nuclear momentum distribution of carbon to obtain the nuclear transparency. We find a sharp rise in transparency as the beam momentum is increased to 9 GeV/c and a reduction to approximately the Glauber level at higher energies.



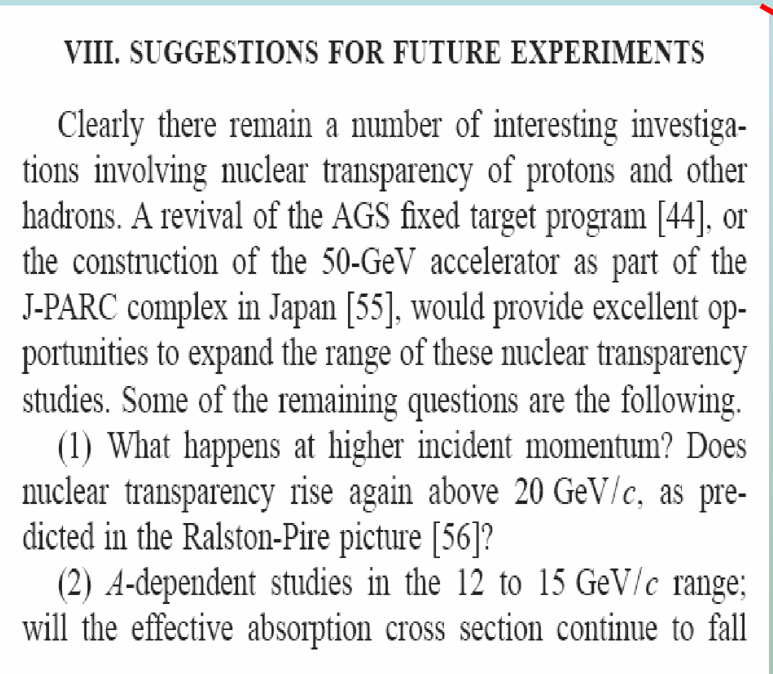
$$T_{\rm CH} = T \int d\alpha \int d^2\vec{P}_{FT}\, n(\alpha, \vec{P}_{FT})\, \frac{(\frac{d\sigma}{dt})_{pp}(s(\alpha))}{(\frac{d\sigma}{dt})_{pp}(s_0)}$$

$$\alpha \equiv A\,\frac{(E_F - P_{Fz})}{M_A} \simeq 1 - \frac{P_{Fz}}{m_p}$$

FIG. 2. Top: The transparency ratio $T_{\rm CH}$ as a function of the beam momentum for both the present result and two points from the 1998 publication [3]. Bottom: The transparency T versus beam momentum. The vertical errors shown here are all statistical errors, which dominate for these measurements. The horizontal errors reflect the α bin used. The shaded band represents the Glauber calculation for carbon [9]. The solid curve shows the shape R^{-1} as defined in the text. The 1998 data cover the c.m. angular region from 86°–90°. For the new data, a similar angular region is covered as is discussed in the text. The 1988 data cover 81°–90° c.m.

COLOR TRANSPARENCY

PHYSICAL REVIEW C **70**, 015208 (2004)

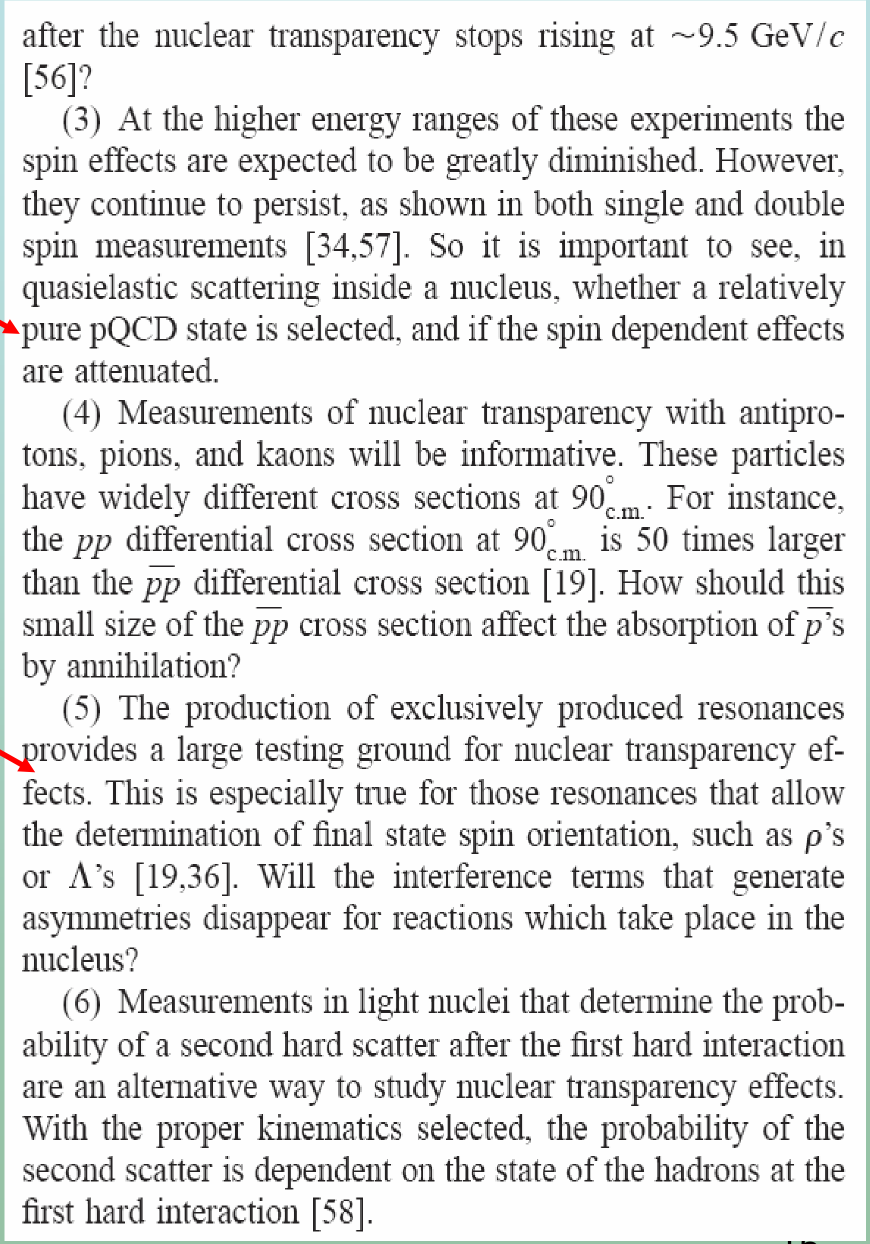


VIII. SUGGESTIONS FOR FUTURE EXPERIMENTS

Clearly there remain a number of interesting investigations involving nuclear transparency of protons and other hadrons. A revival of the AGS fixed target program [44], or the construction of the 50-GeV accelerator as part of the J-PARC complex in Japan [55], would provide excellent opportunities to expand the range of these nuclear transparency studies. Some of the remaining questions are the following.

(1) What happens at higher incident momentum? Does nuclear transparency rise again above 20 GeV/c, as predicted in the Ralston-Pire picture [56]?

(2) A-dependent studies in the 12 to 15 GeV/c range; will the effective absorption cross section continue to fall



after the nuclear transparency stops rising at $\sim$9.5 GeV/c [56]?

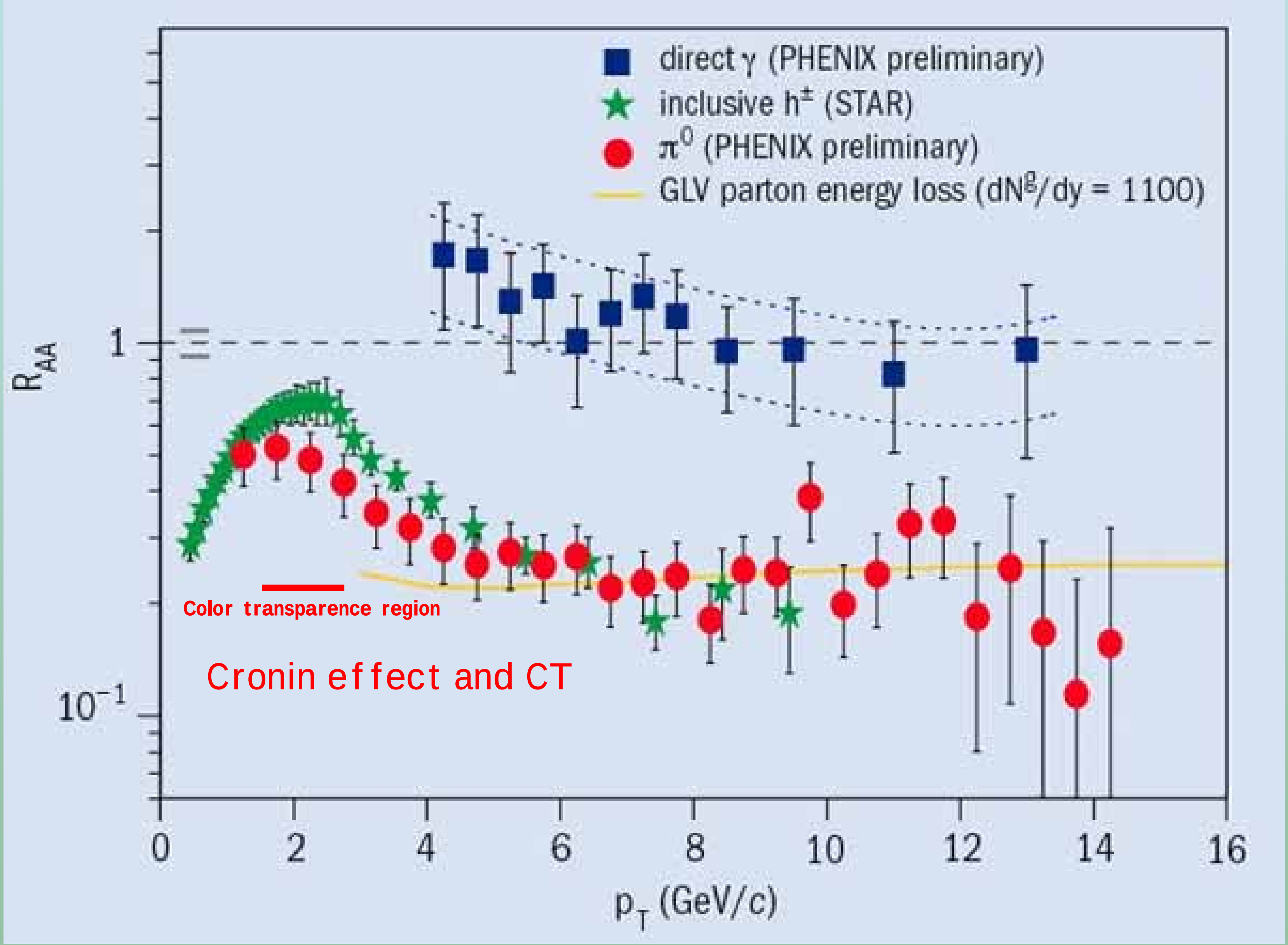
(3) At the higher energy ranges of these experiments the spin effects are expected to be greatly diminished. However, they continue to persist, as shown in both single and double spin measurements [34,57]. So it is important to see, in quasielastic scattering inside a nucleus, whether a relatively pure pQCD state is selected, and if the spin dependent effects are attenuated.

(4) Measurements of nuclear transparency with antiprotons, pions, and kaons will be informative. These particles have widely different cross sections at $90^\circ_{\mathrm{c.m.}}$. For instance, the pp differential cross section at $90^\circ_{\mathrm{c.m.}}$ is 50 times larger than the $\bar{p}p$ differential cross section [19]. How should this small size of the $\bar{p}p$ cross section affect the absorption of $\bar{p}$'s by annihilation?

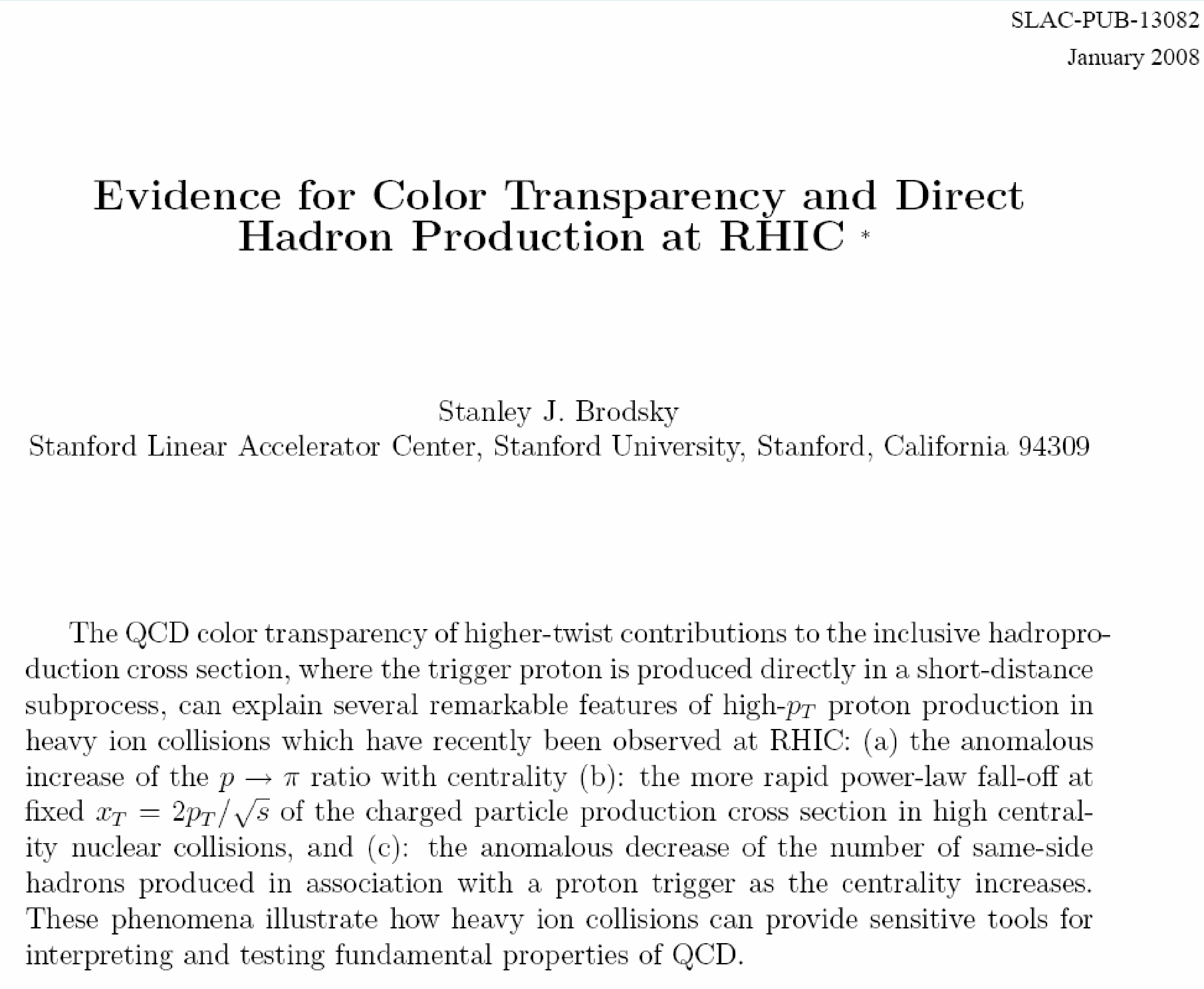
(5) The production of exclusively produced resonances provides a large testing ground for nuclear transparency effects. This is especially true for those resonances that allow the determination of final state spin orientation, such as ρ's or Λ's [19,36]. Will the interference terms that generate asymmetries disappear for reactions which take place in the nucleus?

(6) Measurements in light nuclei that determine the probability of a second hard scatter after the first hard interaction are an alternative way to study nuclear transparency effects. With the proper kinematics selected, the probability of the second scatter is dependent on the state of the hadrons at the first hard interaction [58].

High p_T suppression in AA-collisions



Cronin effect and CT



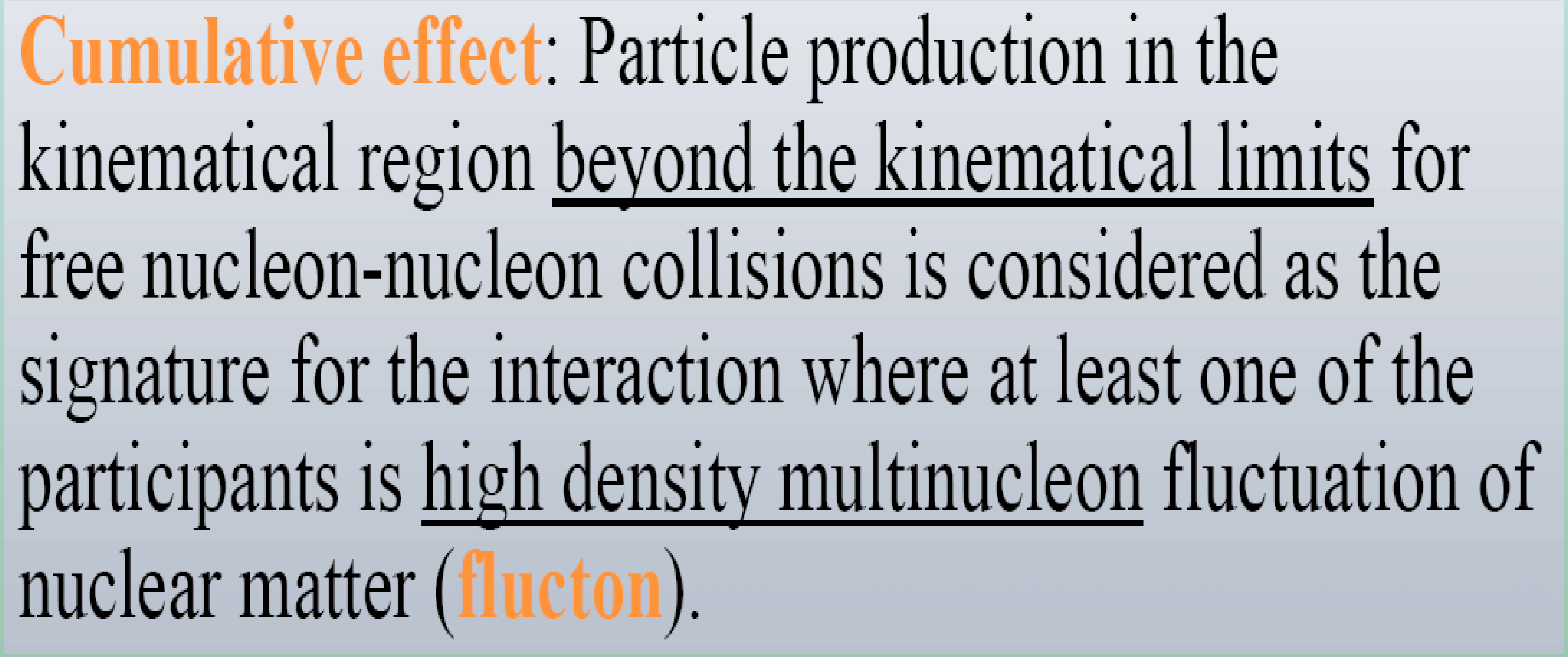
SLAC-PUB-13082
January 2008

Evidence for Color Transparency and Direct Hadron Production at RHIC *

Stanley J. Brodsky
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309

The QCD color transparency of higher-twist contributions to the inclusive hadroproduction cross section, where the trigger proton is produced directly in a short-distance subprocess, can explain several remarkable features of high-p_T proton production in heavy ion collisions which have recently been observed at RHIC: (a) the anomalous increase of the $p \to \pi$ ratio with centrality (b): the more rapid power-law fall-off at fixed $x_T = 2p_T/\sqrt{s}$ of the charged particle production cross section in high centrality nuclear collisions, and (c): the anomalous decrease of the number of same-side hadrons produced in association with a proton trigger as the centrality increases. These phenomena illustrate how heavy ion collisions can provide sensitive tools for interpreting and testing fundamental properties of QCD.

Cumulative and Subthreshold processes



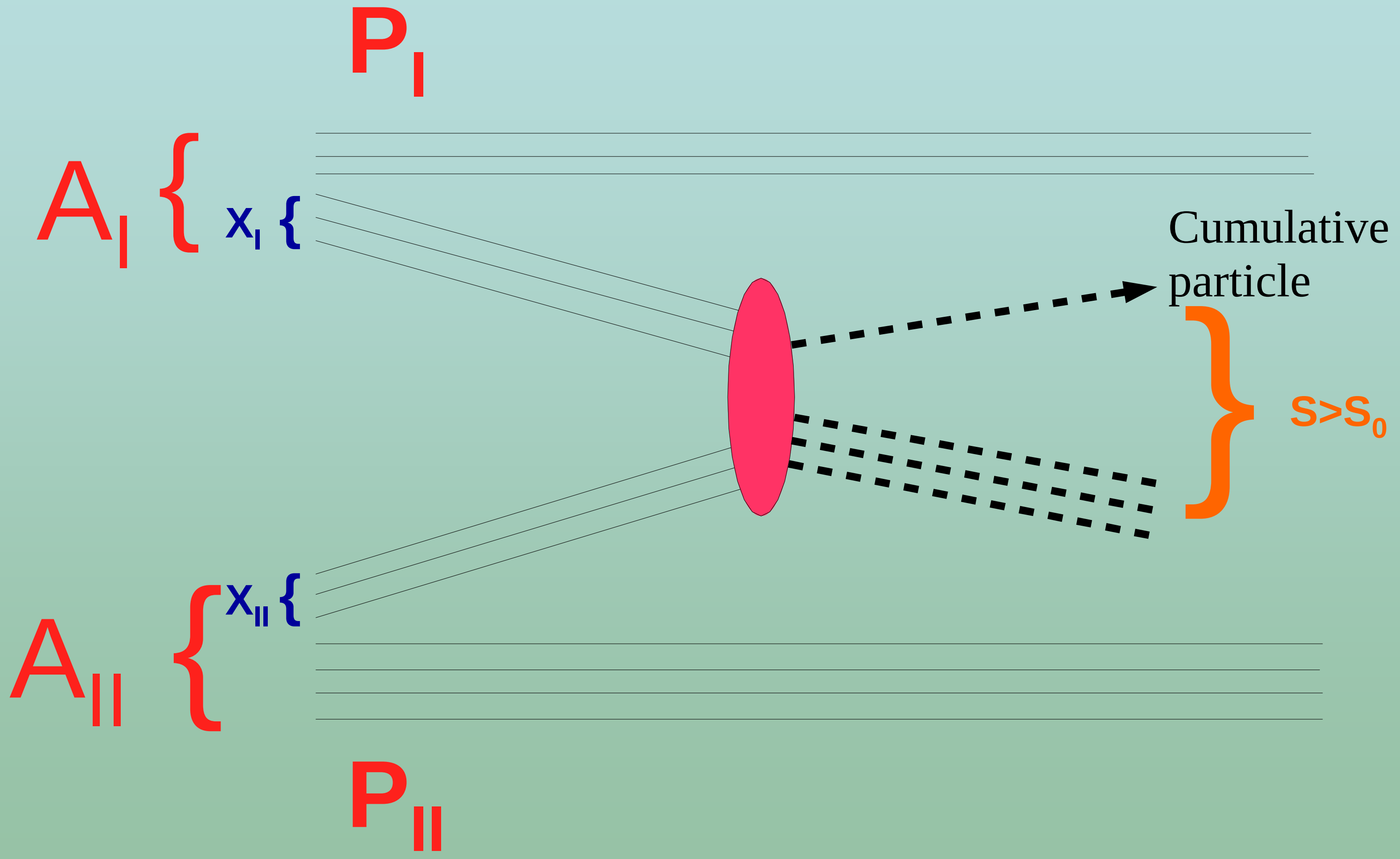
Cumulative effect: Particle production in the kinematical region beyond the kinematical limits for free nucleon-nucleon collisions is considered as the signature for the interaction where at least one of the participants is high density multinucleon fluctuation of nuclear matter (**flucton**).

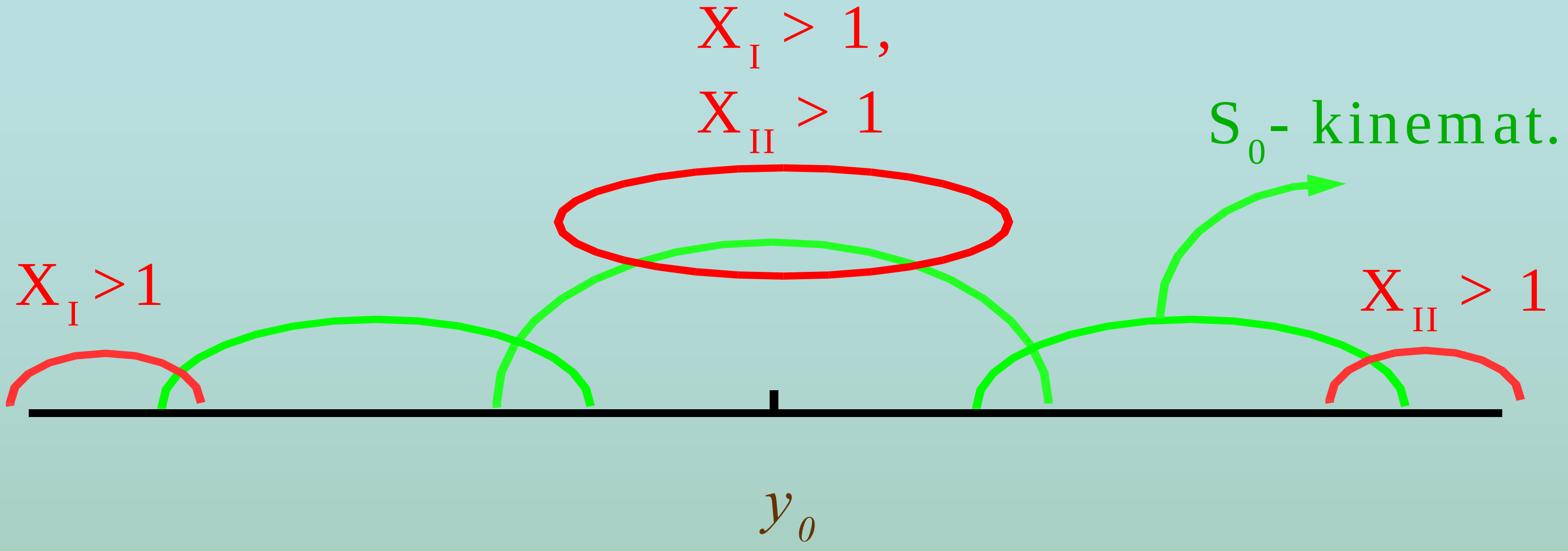
V.S. Stavinsky JINR Rapid Communications N18-86, p.5 (1986)

$$(X_I \cdot M_I) + (X_{II} \cdot M_{II}) \to m_c + [X_I \cdot M_I + X_{II} \cdot M_{II} + m_2]$$

Quark-parton model

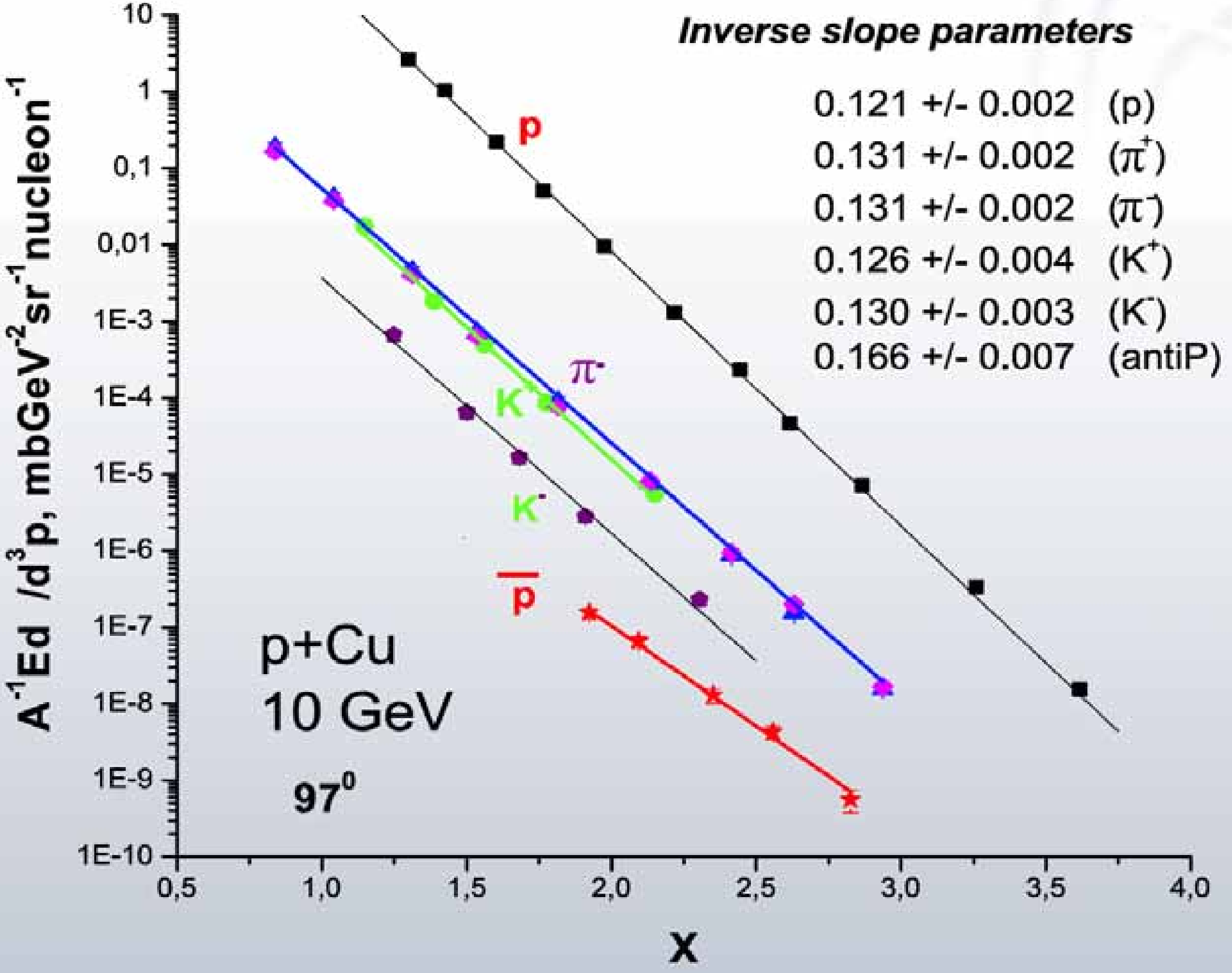
$$(X_I \cdot P_I) + (X_{II} \cdot P_{II}) \to M(X_I, X_{II})$$





Cumulative processes:

1) $X_I = 1$ and $X_{II} > 1$ } Fragmentation
2) $X_{II} = 1$ and $X_I > 1$ } regions
3) $X_I > 1$ and $X_{II} > 1$ Central region



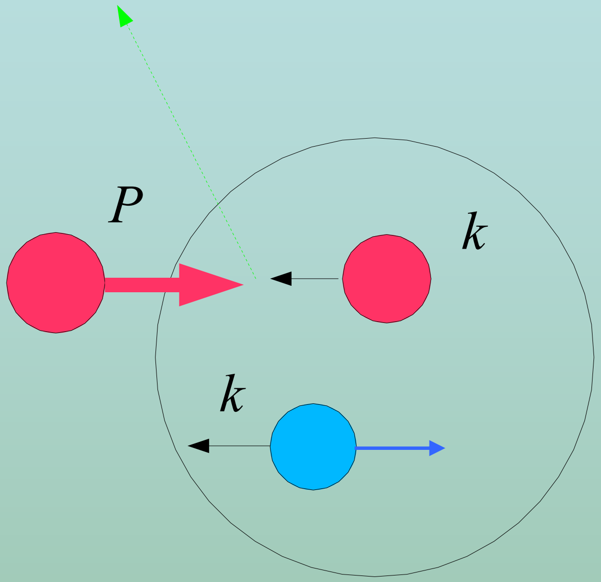
Inverse slope parameters

0.121 +/- 0.002	(p)
0.131 +/- 0.002	(π^+)
0.131 +/- 0.002	(π^-)
0.126 +/- 0.004	(K^+)
0.130 +/- 0.003	(K^-)
0.166 +/- 0.007	(antiP)

FAS @ ITEP
(Boyarinov et.al
Yad.Fiz 57
(1994) 1452)

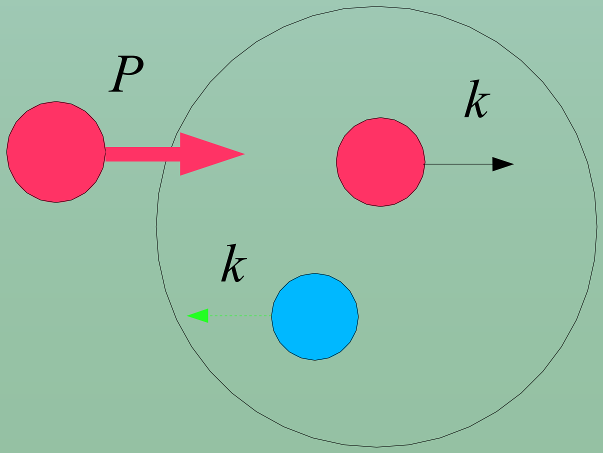
X – minimal target mass [m_N] needed to produce particle

Fermi motion or Short Range Correlation (SRC) mechanism



$$p + A \to \pi, \kappa, \bar{p}, \ldots + X$$

$$\sigma_\pi \sim n(\vec{k}) \cdot \sigma(NN \to \pi, K + X)$$

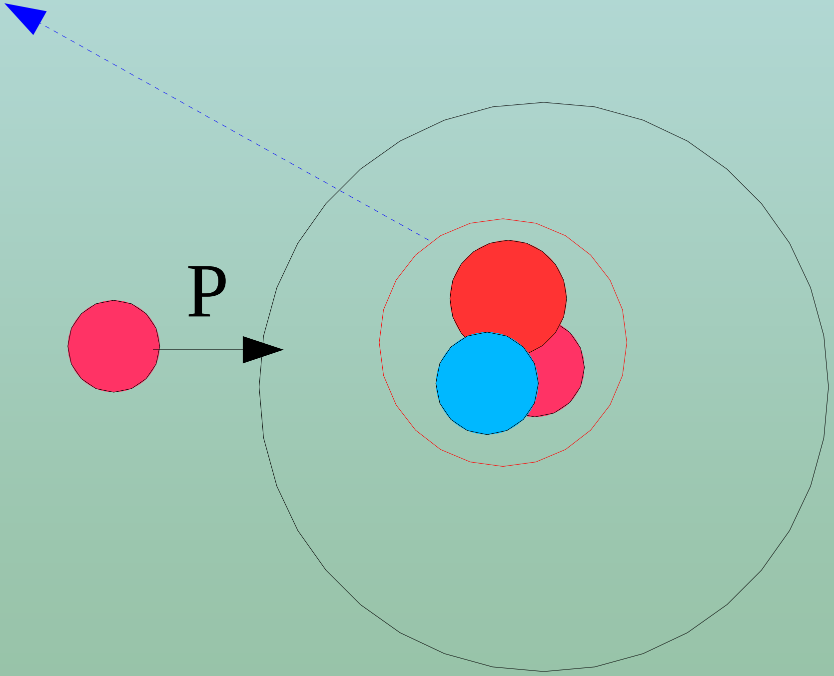


$$p + A \to n, p, \ldots + X$$

$$\sigma_N \sim n(\vec{k}) \cdot \sigma_0$$

Flucton hypothesis

$$p + A \to \pi, \kappa, \bar{p}, p, n, \ldots + X$$



$$\sigma_h \sim P_K \cdot G_{h/K}(K)$$

A.A. Baldin's parameterization

Phys. At. Nucl. 56(3), p.385(1993)

$$\Pi = \frac{1}{2}\left(X_I^2 + X_{II}^2 + 2\cdot X_I \cdot X_{II} \cdot \gamma_{I,II}\right)^{\frac{1}{2}} = \frac{1}{2\cdot m}\cdot S_{\min}^{\frac{1}{2}}$$

$$\gamma_{I,II} = \frac{(P_I \cdot P_{II})}{M_I \cdot M_{II}}$$

Inclusive data parameterization

$$E\cdot\frac{d^3\sigma}{dp^3} = C_1 \cdot A_I^{\frac{1}{3}+\frac{X_I}{3}} \cdot A_{II}^{\frac{1}{3}+\frac{X_{II}}{3}} \cdot \exp\left(-\frac{\Pi}{C_2}\right),$$

$$C_1 = 2200[mb\cdot GeV^{-2}\cdot c^3\cdot sr^{-1}], C_2 = 0.127$$

A.A. Baldin's parameterization for cumulative and subthreshold particle production

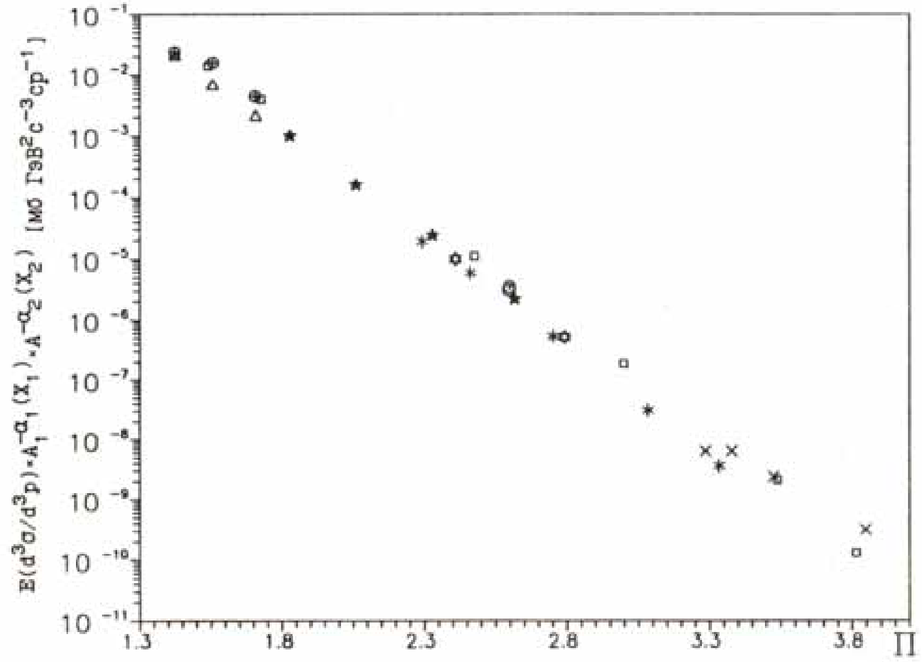
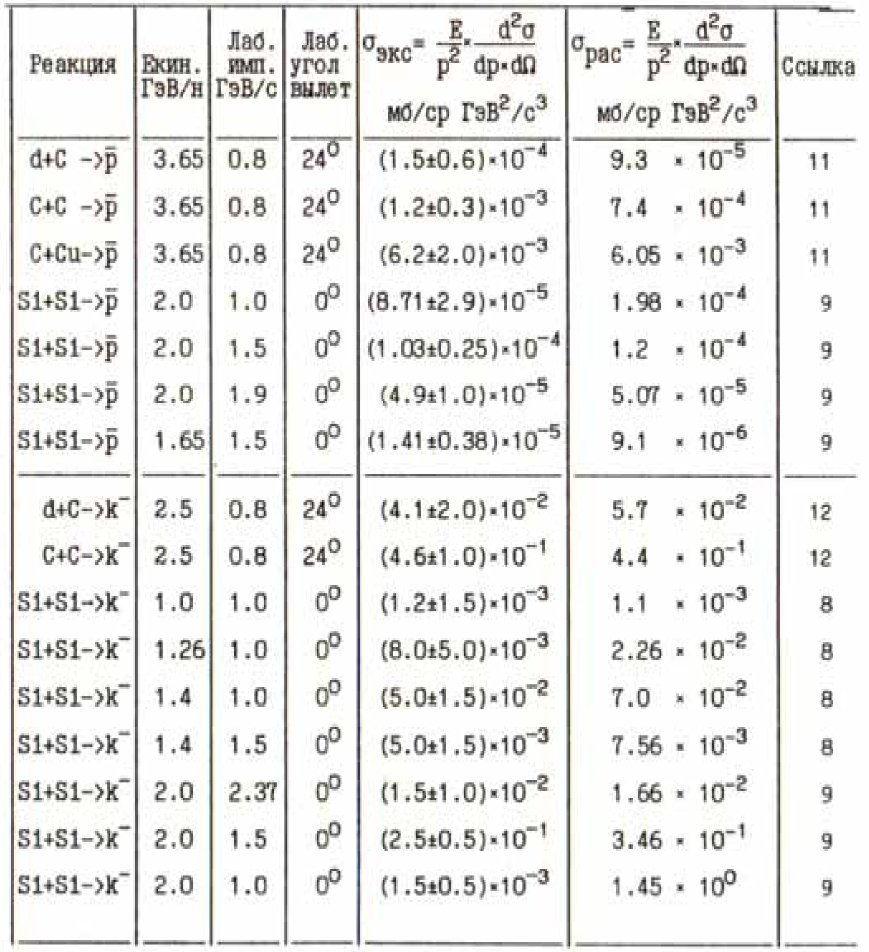


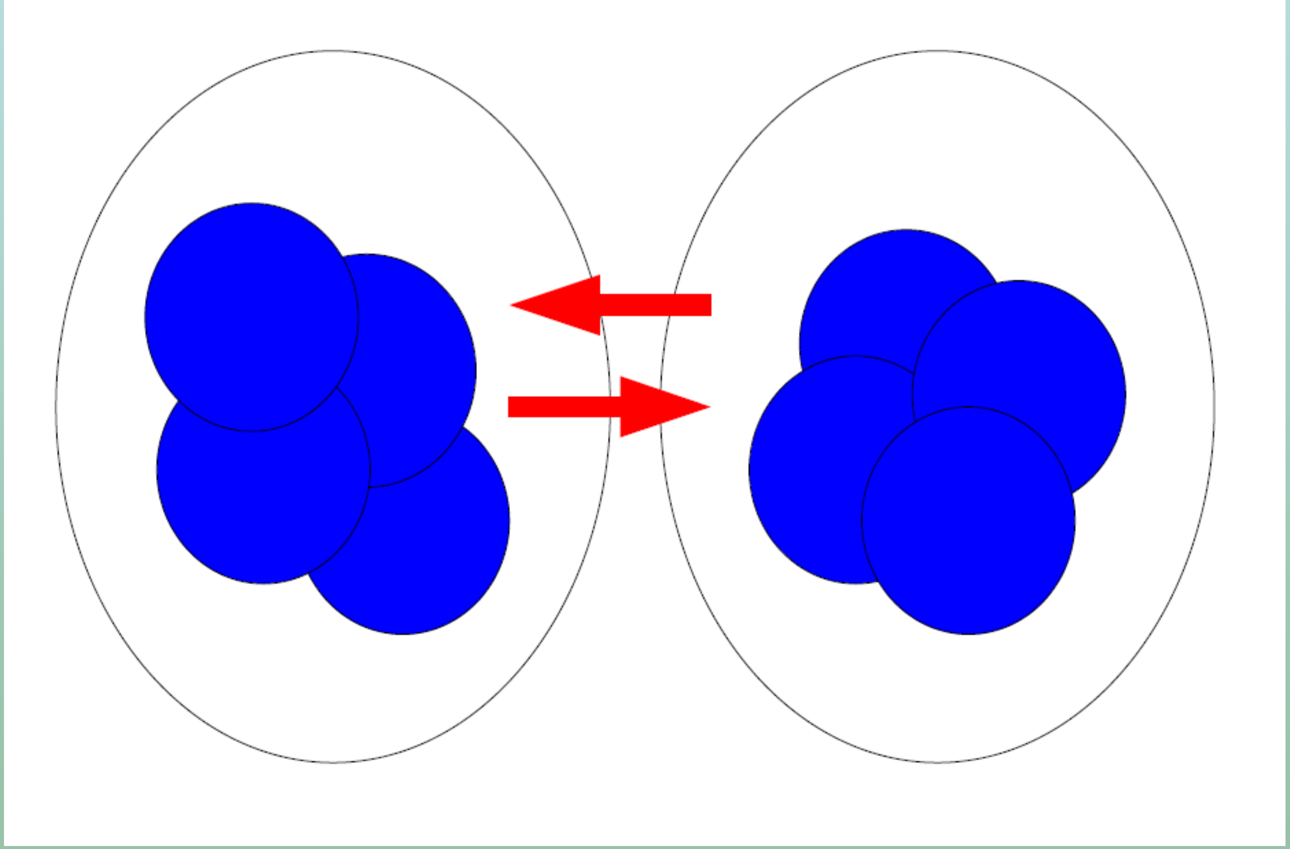
Рис.1. Зависимость инвариантных дифференциальных сечений, деленных на $A^{\alpha_1(X_1)}A^{\alpha_2(X_2)}$, где $\alpha_1(X_1) = 2/3 + X_1/3$ и $\alpha_2(X_2) = 2/3 + X_2/3$, от параметра П для следующих реакций: * Si + Si → K^- 2,0 ГэВ/нуклон, 0°[9]; × Si + Si → $\bar{p}$ 2,0 ГэВ/нуклон, 0°[9]; ✡ Si + Si → K^- 1,4 ГэВ/нуклон, 0°[8] o C + C → $\bar{p}$ 3,65 ГэВ/нуклон, 24°[11]; o $d + C \to \bar{p}$ 3,65 ГэВ/нуклон, 24°[11]; ⊕ $C + C \to K^-$ 2,5—3,65 ГэВ/нуклон, 24°[12]; Δ $d + C \to K^-$ 2,5—3,65 ГэВ/нуклон, 24°[12]; • $p + C \to K^-$ 9,2 ГэВ/нуклон, 119°[6]; □ p + C → π^- 9,2 ГэВ/нуклон, 119°[7]

30



Реакция	Екин. ГэВ/н	Лаб. имп. ГэВ/с	Лаб. угол вылет	$\sigma_{экс} = \frac{E}{p^2}\cdot\frac{d^2\sigma}{dp\cdot d\Omega}$ мб/ср ГэВ^2/с^3	$\sigma_{рас} = \frac{E}{p^2}\cdot\frac{d^2\sigma}{dp\cdot d\Omega}$ мб/ср ГэВ^2/с^3	Ссылка
d+C ->$\bar{p}$	3.65	0.8	24^0	$(1.5\pm0.6)\cdot10^{-4}$	$9.3 \cdot 10^{-5}$	11
C+C ->$\bar{p}$	3.65	0.8	24^0	$(1.2\pm0.3)\cdot10^{-3}$	$7.4 \cdot 10^{-4}$	11
C+Cu->$\bar{p}$	3.65	0.8	24^0	$(6.2\pm2.0)\cdot10^{-3}$	$6.05 \cdot 10^{-3}$	11
S1+S1->$\bar{p}$	2.0	1.0	0^0	$(8.71\pm2.9)\cdot10^{-5}$	$1.98 \cdot 10^{-4}$	9
S1+S1->$\bar{p}$	2.0	1.5	0^0	$(1.03\pm0.25)\cdot10^{-4}$	$1.2 \cdot 10^{-4}$	9
S1+S1->$\bar{p}$	2.0	1.9	0^0	$(4.9\pm1.0)\cdot10^{-5}$	$5.07 \cdot 10^{-5}$	9
S1+S1->$\bar{p}$	1.65	1.5	0^0	$(1.41\pm0.38)\cdot10^{-5}$	$9.1 \cdot 10^{-6}$	9
d+C->k^-	2.5	0.8	24^0	$(4.1\pm2.0)\cdot10^{-2}$	$5.7 \cdot 10^{-2}$	12
C+C->k^-	2.5	0.8	24^0	$(4.6\pm1.0)\cdot10^{-1}$	$4.4 \cdot 10^{-1}$	12
S1+S1->k^-	1.0	1.0	0^0	$(1.2\pm1.5)\cdot10^{-3}$	$1.1 \cdot 10^{-3}$	8
S1+S1->k^-	1.26	1.0	0^0	$(8.0\pm5.0)\cdot10^{-3}$	$2.26 \cdot 10^{-2}$	8
S1+S1->k^-	1.4	1.0	0^0	$(5.0\pm1.5)\cdot10^{-2}$	$7.0 \cdot 10^{-2}$	8
S1+S1->k^-	1.4	1.5	0^0	$(5.0\pm1.5)\cdot10^{-3}$	$7.56 \cdot 10^{-3}$	8
S1+S1->k^-	2.0	2.37	0^0	$(1.5\pm1.0)\cdot10^{-2}$	$1.66 \cdot 10^{-2}$	9
S1+S1->k^-	2.0	1.5	0^0	$(2.5\pm0.5)\cdot10^{-1}$	$3.46 \cdot 10^{-1}$	9
S1+S1->k^-	2.0	1.0	0^0	$(1.5\pm0.5)\cdot10^{-3}$	$1.45 \cdot 10^{0}$	9

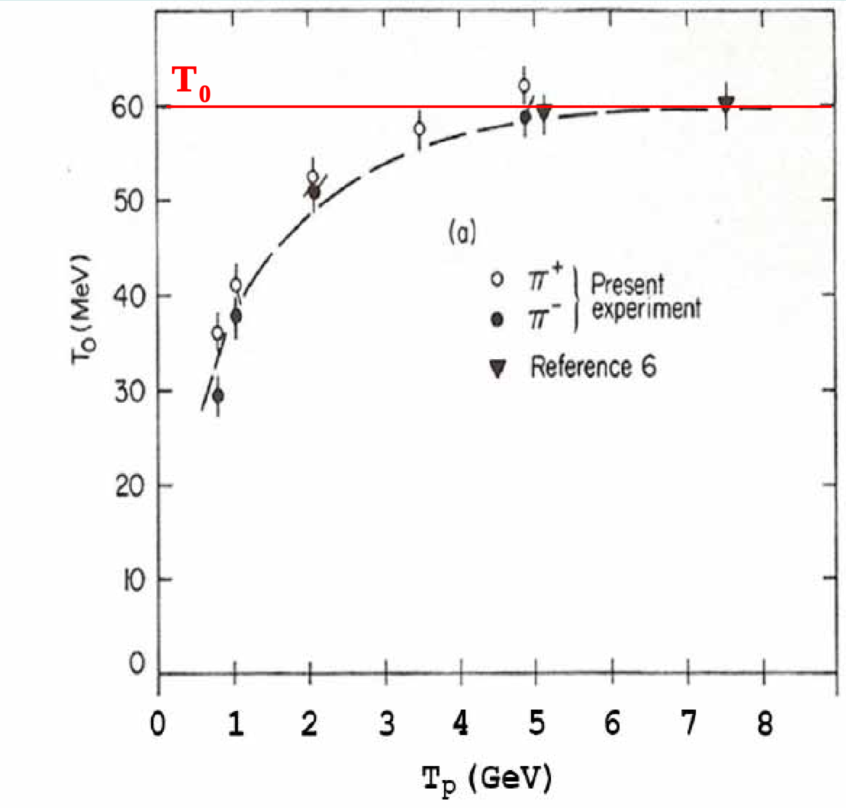
Subthreshold particleproduction in to the flucton-flucton mechanism



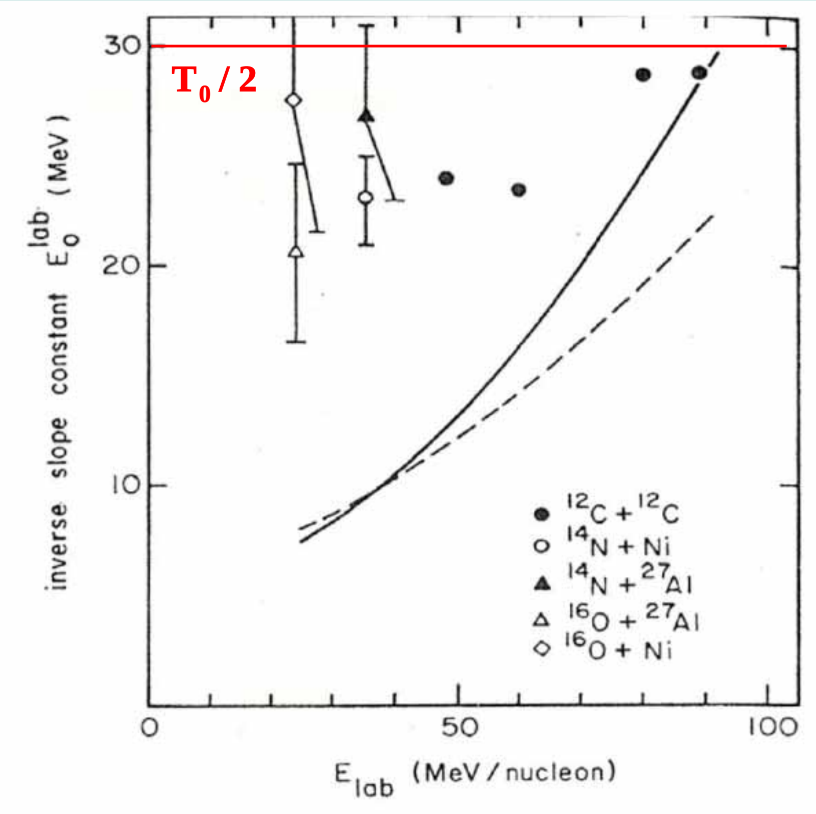
$$\sigma_h \sim P^2{}_K \cdot G^2{}_{h/K}(K)$$

Inverse slope for subthreshold production must be the less then $T_0/2$ (near the phase space border).

L.S. Schreder et al.,PRL,1787(1979)



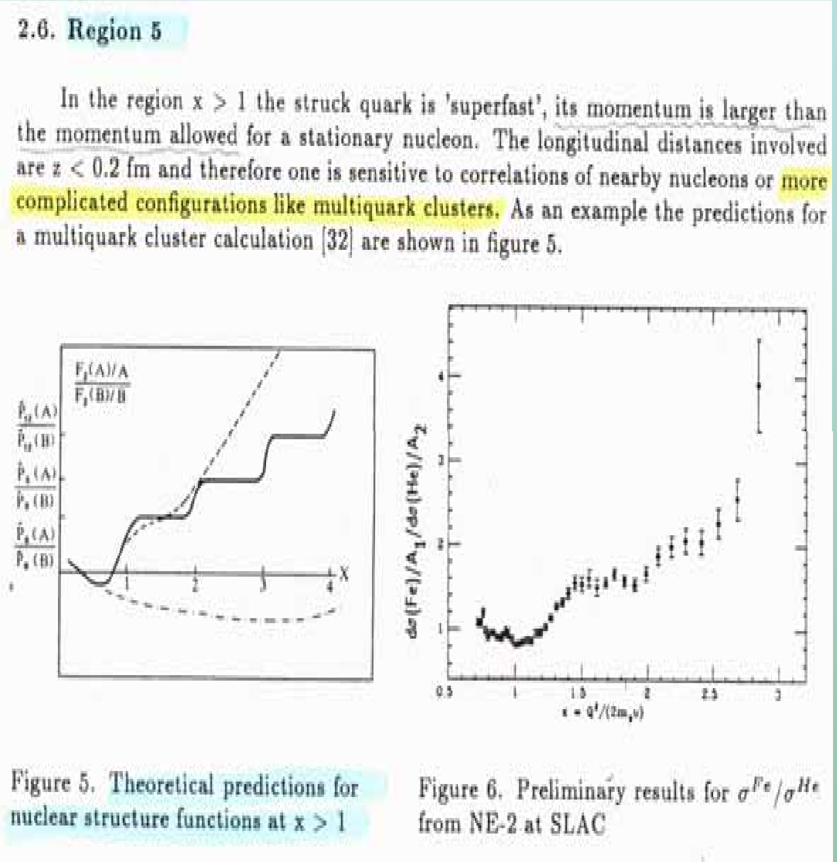
J.Stachel et al.,Phys.Rev.C33,N4(1986)



$$P_{cum} \sim \exp\left(-T/T_0\right) \quad \Rightarrow \quad P_{subthresh} \sim \exp\left(-T/T_0\right) \cdot \exp\left(-T/T_0\right) \sim \exp\left(-T/(T_0/2)\right)$$

DIS with leptons

K.Rith From Nuclei to Nucleons (Summary)
Nuclear Physics A532 (1991) 3c-14c

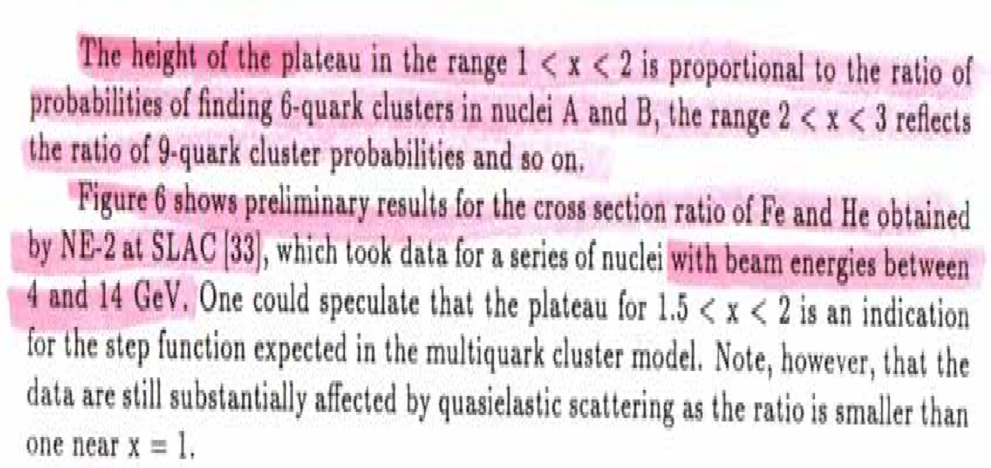


2.6. Region 5

In the region x > 1 the struck quark is 'superfast', its momentum is larger than the momentum allowed for a stationary nucleon. The longitudinal distances involved are $z < 0.2$ fm and therefore one is sensitive to correlations of nearby nucleons or more complicated configurations like multiquark clusters. As an example the predictions for a multiquark cluster calculation [32] are shown in figure 5.

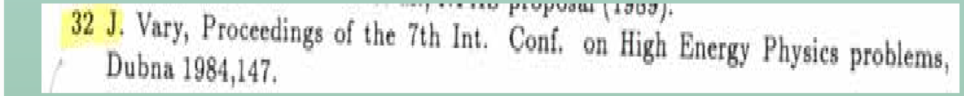
Figure 5. Theoretical predictions for nuclear structure functions at x > 1

Figure 6. Preliminary results for σ^{Fe}/σ^{He} from NE-2 at SLAC

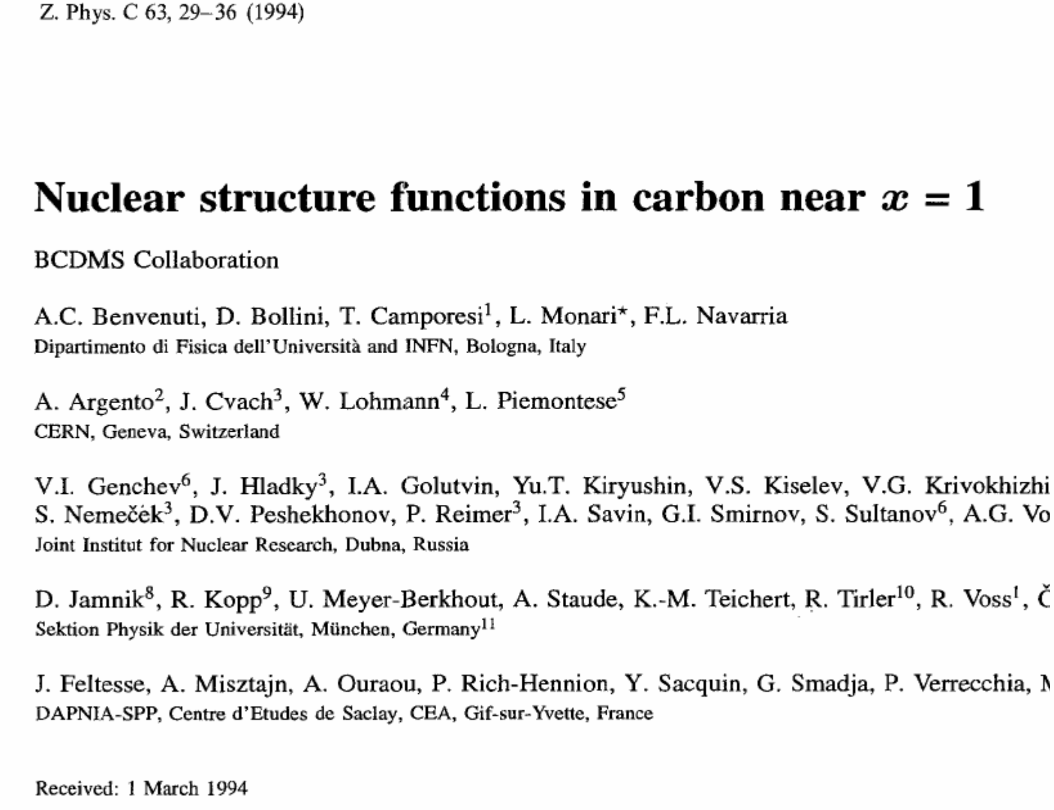


The height of the plateau in the range $1 < x < 2$ is proportional to the ratio of probabilities of finding 6-quark clusters in nuclei A and B, the range $2 < x < 3$ reflects the ratio of 9-quark cluster probabilities and so on.

Figure 6 shows preliminary results for the cross section ratio of Fe and He obtained by NE-2 at SLAC [33], which took data for a series of nuclei with beam energies between 4 and 14 GeV. One could speculate that the plateau for $1.5 < x < 2$ is an indication for the step function expected in the multiquark cluster model. Note, however, that the data are still substantially affected by quasielastic scattering as the ratio is smaller than one near x = 1.



32 J. Vary, Proceedings of the 7th Int. Conf. on High Energy Physics problems, Dubna 1984,147.



Z. Phys. C 63, 29–36 (1994)

ZEITSCHRIFT
FÜR PHYSIK C

Nuclear structure functions in carbon near $x = 1$

BCDMS Collaboration

A.C. Benvenuti, D. Bollini, T. Camporesi[1], L. Monari*, F.L. Navarria
Dipartimento di Fisica dell'Università and INFN, Bologna, Italy

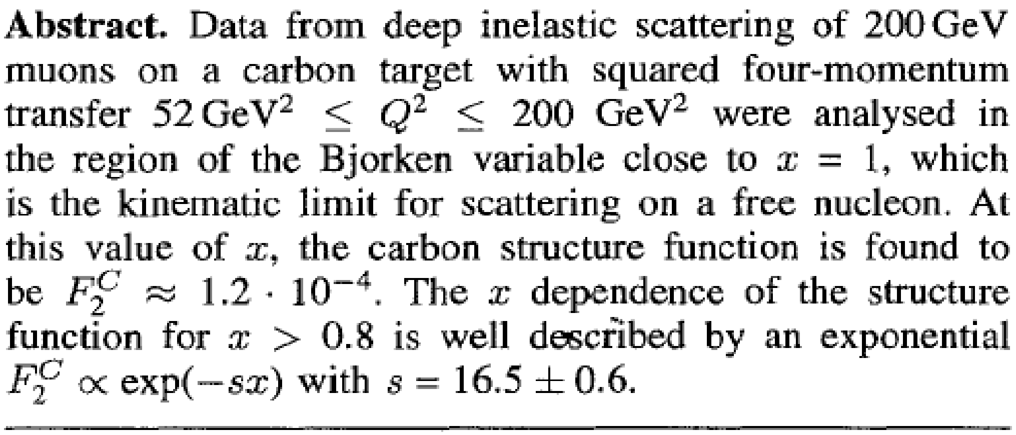
A. Argento[2], J. Cvach[3], W. Lohmann[4], L. Piemontese[5]
CERN, Geneva, Switzerland

V.I. Genchev[6], J. Hladky[3], I.A. Golutvin, Yu.T. Kiryushin, V.S. Kiselev, V.G. Krivokhizhi
S. Nemeček[3], D.V. Peshekhonov, P. Reimer[3], I.A. Savin, G.I. Smirnov, S. Sultanov[6], A.G. Vo
Joint Institut for Nuclear Research, Dubna, Russia

D. Jamnik[8], R. Kopp[9], U. Meyer-Berkhout, A. Staude, K.-M. Teichert, R. Tirler[10], R. Voss[1], Č
Sektion Physik der Universität, München, Germany[11]

J. Feltesse, A. Misztajn, A. Ouraou, P. Rich-Hennion, Y. Sacquin, G. Smadja, P. Verrecchia, N
DAPNIA-SPP, Centre d'Etudes de Saclay, CEA, Gif-sur-Yvette, France

Received: 1 March 1994



Abstract. Data from deep inelastic scattering of 200 GeV muons on a carbon target with squared four-momentum transfer $52\,\text{GeV}^2 \leq Q^2 \leq 200\ \text{GeV}^2$ were analysed in the region of the Bjorken variable close to $x = 1$, which is the kinematic limit for scattering on a free nucleon. At this value of x, the carbon structure function is found to be $F_2^C \approx 1.2 \cdot 10^{-4}$. The x dependence of the structure function for $x > 0.8$ is well described by an exponential $F_2^C \propto \exp(-sx)$ with $s = 16.5 \pm 0.6$.

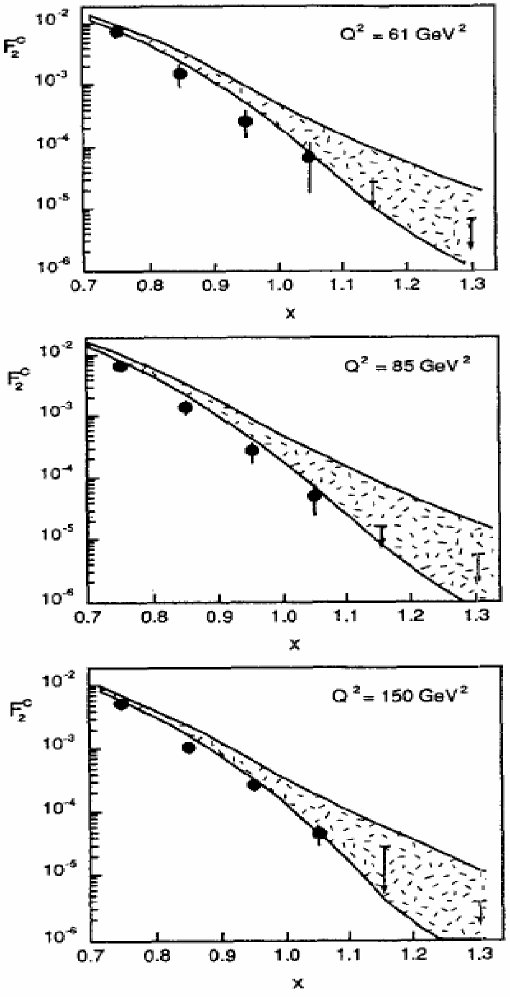
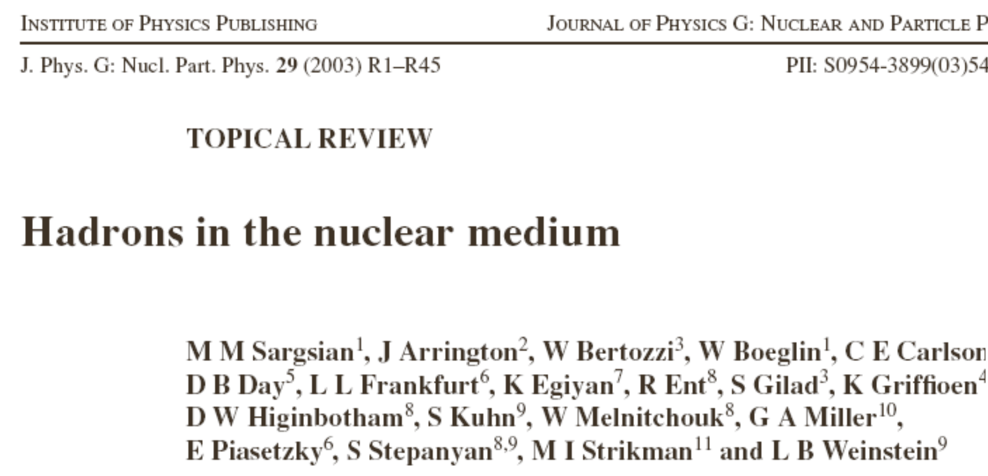


Fig. 7. The nuclear structure function $F_2^C(x)$ as a function of x, at three different values of Q^2. The hatched regions show the range of predictions of [26]

Shimanskiy S.S.

JLAB data



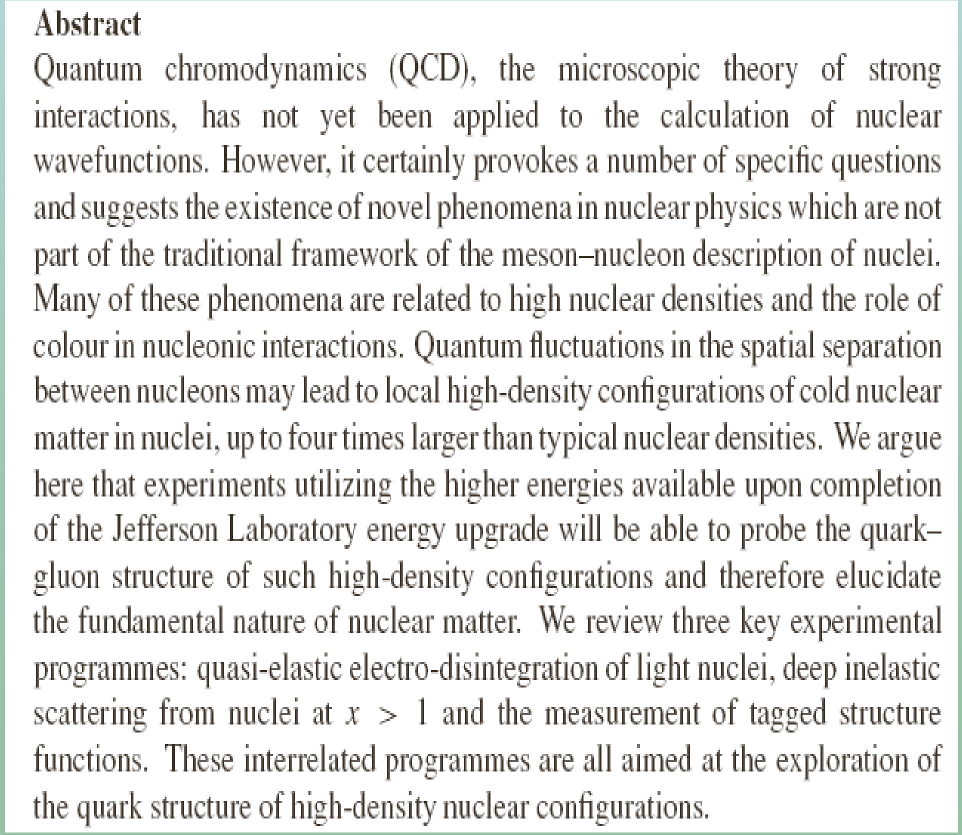
INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS G: NUCLEAR AND PARTICLE PHYSICS

J. Phys. G: Nucl. Part. Phys. **29** (2003) R1–R45 PII: S0954-3899(03)54926-X

TOPICAL REVIEW

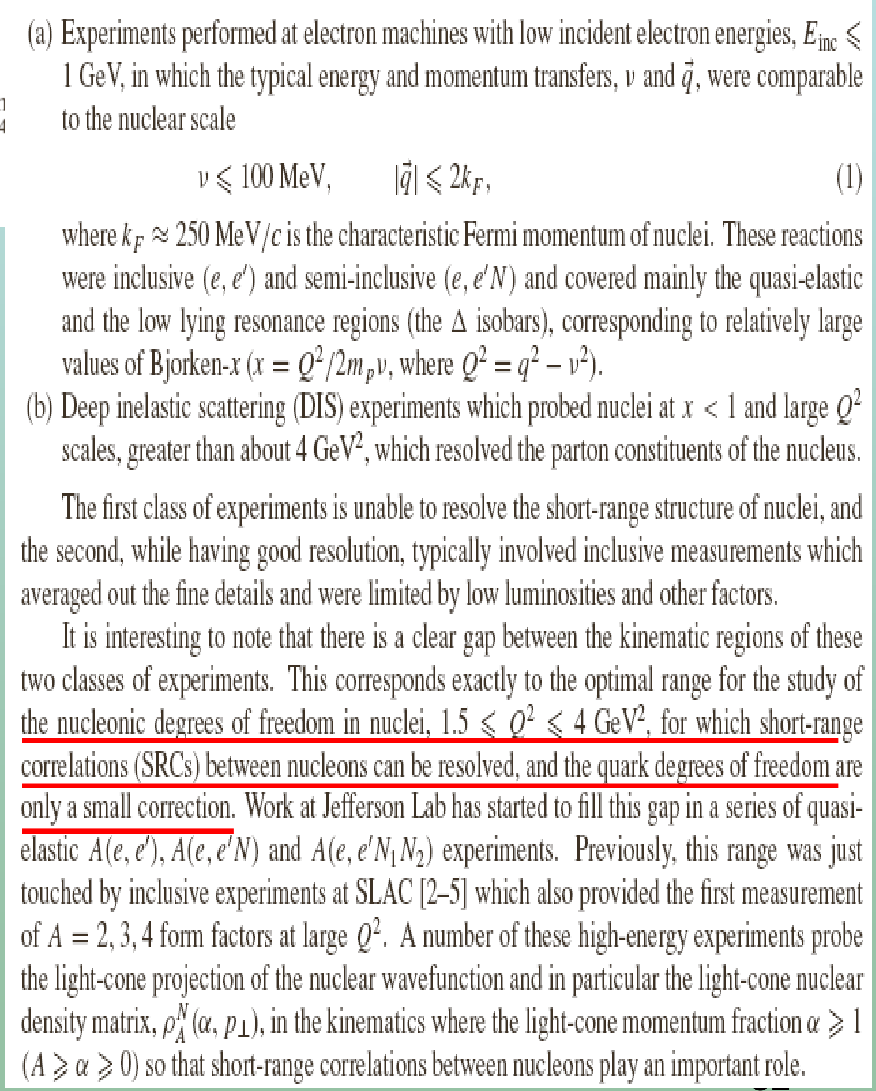
Hadrons in the nuclear medium

M M Sargsian[1], J Arrington[2], W Bertozzi[3], W Boeglin[1], C E Carlson
D B Day[5], L L Frankfurt[6], K Egiyan[7], R Ent[8], S Gilad[3], K Griffioen[4]
D W Higinbotham[8], S Kuhn[9], W Melnitchouk[8], G A Miller[10],
E Piasetzky[6], S Stepanyan[8,9], M I Strikman[11] and L B Weinstein[9]



Abstract

Quantum chromodynamics (QCD), the microscopic theory of strong interactions, has not yet been applied to the calculation of nuclear wavefunctions. However, it certainly provokes a number of specific questions and suggests the existence of novel phenomena in nuclear physics which are not part of the traditional framework of the meson–nucleon description of nuclei. Many of these phenomena are related to high nuclear densities and the role of colour in nucleonic interactions. Quantum fluctuations in the spatial separation between nucleons may lead to local high-density configurations of cold nuclear matter in nuclei, up to four times larger than typical nuclear densities. We argue here that experiments utilizing the higher energies available upon completion of the Jefferson Laboratory energy upgrade will be able to probe the quark–gluon structure of such high-density configurations and therefore elucidate the fundamental nature of nuclear matter. We review three key experimental programmes: quasi-elastic electro-disintegration of light nuclei, deep inelastic scattering from nuclei at $x > 1$ and the measurement of tagged structure functions. These interrelated programmes are all aimed at the exploration of the quark structure of high-density nuclear configurations.



(a) Experiments performed at electron machines with low incident electron energies, $E_{\mathrm{inc}} \leqslant 1$ GeV, in which the typical energy and momentum transfers, ν and $\vec{q}$, were comparable to the nuclear scale

$$\nu \leqslant 100\ \mathrm{MeV}, \qquad |\vec{q}| \leqslant 2k_F, \tag{1}$$

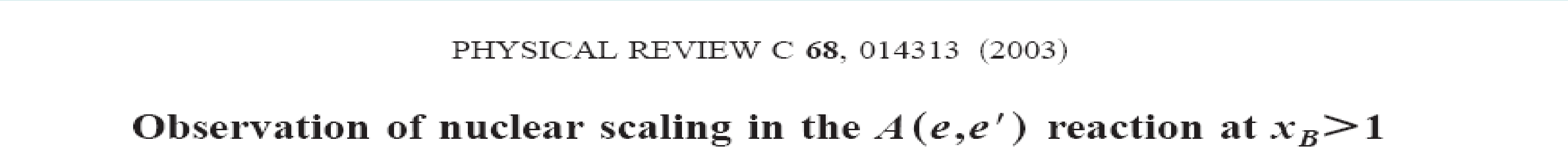
where $k_F \approx 250\ \mathrm{MeV}/c$ is the characteristic Fermi momentum of nuclei. These reactions were inclusive (e, e') and semi-inclusive $(e, e'N)$ and covered mainly the quasi-elastic and the low lying resonance regions (the Δ isobars), corresponding to relatively large values of Bjorken-x ($x = Q^2/2m_p\nu$, where $Q^2 = q^2 - \nu^2$).

(b) Deep inelastic scattering (DIS) experiments which probed nuclei at $x < 1$ and large Q^2 scales, greater than about 4 GeV^2, which resolved the parton constituents of the nucleus.

The first class of experiments is unable to resolve the short-range structure of nuclei, and the second, while having good resolution, typically involved inclusive measurements which averaged out the fine details and were limited by low luminosities and other factors.

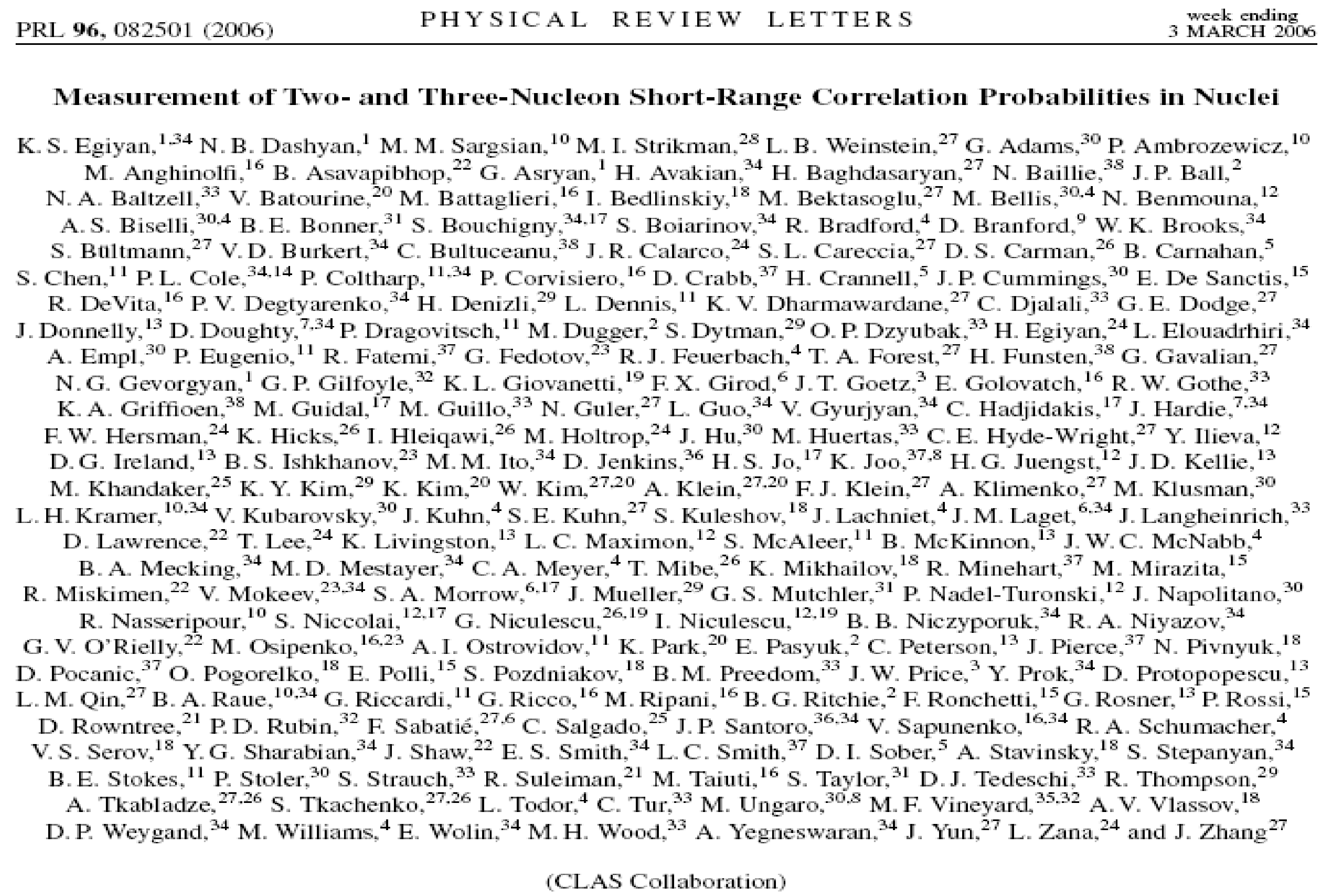
It is interesting to note that there is a clear gap between the kinematic regions of these two classes of experiments. This corresponds exactly to the optimal range for the study of the nucleonic degrees of freedom in nuclei, $1.5 \leqslant Q^2 \leqslant 4$ GeV^2, for which short-range correlations (SRCs) between nucleons can be resolved, and the quark degrees of freedom are only a small correction. Work at Jefferson Lab has started to fill this gap in a series of quasi-elastic $A(e, e')$, $A(e, e'N)$ and $A(e, e'N_1N_2)$ experiments. Previously, this range was just touched by inclusive experiments at SLAC [2–5] which also provided the first measurement of $A = 2, 3, 4$ form factors at large Q^2. A number of these high-energy experiments probe the light-cone projection of the nuclear wavefunction and in particular the light-cone nuclear density matrix, $\rho_A^N(\alpha, p_\perp)$, in the kinematics where the light-cone momentum fraction $\alpha \geqslant 1$ $(A \geqslant \alpha \geqslant 0)$ so that short-range correlations between nucleons play an important role.

JLAB data



PHYSICAL REVIEW C **68**, 014313 (2003)

Observation of nuclear scaling in the $A(e,e')$ reaction at $x_B>1$



PRL **96**, 082501 (2006) PHYSICAL REVIEW LETTERS week ending 3 MARCH 2006

Measurement of Two- and Three-Nucleon Short-Range Correlation Probabilities in Nuclei

K. S. Egiyan,[1,34] N. B. Dashyan,[1] M. M. Sargsian,[10] M. I. Strikman,[28] L. B. Weinstein,[27] G. Adams,[30] P. Ambrozewicz,[10] M. Anghinolfi,[16] B. Asavapibhop,[22] G. Asryan,[1] H. Avakian,[34] H. Baghdasaryan,[27] N. Baillie,[38] J. P. Ball,[2] N. A. Baltzell,[33] V. Batourine,[20] M. Battaglieri,[16] I. Bedlinskiy,[18] M. Bektasoglu,[27] M. Bellis,[30,4] N. Benmouna,[12] A. S. Biselli,[30,4] B. E. Bonner,[31] S. Bouchigny,[34,17] S. Boiarinov,[34] R. Bradford,[4] D. Branford,[9] W. K. Brooks,[34] S. Bültmann,[27] V. D. Burkert,[34] C. Bultuceanu,[38] J. R. Calarco,[24] S. L. Careccia,[27] D. S. Carman,[26] B. Carnahan,[5] S. Chen,[11] P. L. Cole,[34,14] P. Coltharp,[11,34] P. Corvisiero,[16] D. Crabb,[37] H. Crannell,[5] J. P. Cummings,[30] E. De Sanctis,[15] R. DeVita,[16] P. V. Degtyarenko,[34] H. Denizli,[29] L. Dennis,[11] K. V. Dharmawardane,[27] C. Djalali,[33] G. E. Dodge,[27] J. Donnelly,[13] D. Doughty,[7,34] P. Dragovitsch,[11] M. Dugger,[2] S. Dytman,[29] O. P. Dzyubak,[33] H. Egiyan,[24] L. Elouadrhiri,[34] A. Empl,[30] P. Eugenio,[11] R. Fatemi,[37] G. Fedotov,[23] R. J. Feuerbach,[4] T. A. Forest,[27] H. Funsten,[38] G. Gavalian,[27] N. G. Gevorgyan,[1] G. P. Gilfoyle,[32] K. L. Giovanetti,[19] F. X. Girod,[6] J. T. Goetz,[3] E. Golovatch,[16] R. W. Gothe,[33] K. A. Griffioen,[38] M. Guidal,[17] M. Guillo,[33] N. Guler,[27] L. Guo,[34] V. Gyurjyan,[34] C. Hadjidakis,[17] J. Hardie,[7,34] F. W. Hersman,[24] K. Hicks,[26] I. Hleiqawi,[26] M. Holtrop,[24] J. Hu,[30] M. Huertas,[33] C. E. Hyde-Wright,[27] Y. Ilieva,[12] D. G. Ireland,[13] B. S. Ishkhanov,[23] M. M. Ito,[34] D. Jenkins,[36] H. S. Jo,[17] K. Joo,[37,8] H. G. Juengst,[12] J. D. Kellie,[13] M. Khandaker,[25] K. Y. Kim,[29] K. Kim,[20] W. Kim,[27,20] A. Klein,[27,20] F. J. Klein,[27] A. Klimenko,[27] M. Klusman,[30] L. H. Kramer,[10,34] V. Kubarovsky,[30] J. Kuhn,[4] S. E. Kuhn,[27] S. Kuleshov,[18] J. Lachniet,[4] J. M. Laget,[6,34] J. Langheinrich,[33] D. Lawrence,[22] T. Lee,[24] K. Livingston,[13] L. C. Maximon,[12] S. McAleer,[11] B. McKinnon,[13] J. W. C. McNabb,[4] B. A. Mecking,[34] M. D. Mestayer,[34] C. A. Meyer,[4] T. Mibe,[26] K. Mikhailov,[18] R. Minehart,[37] M. Mirazita,[15] R. Miskimen,[22] V. Mokeev,[23,34] S. A. Morrow,[6,17] J. Mueller,[29] G. S. Mutchler,[31] P. Nadel-Turonski,[12] J. Napolitano,[30] R. Nasseripour,[10] S. Niccolai,[12,17] G. Niculescu,[26,19] I. Niculescu,[12,19] B. B. Niczyporuk,[34] R. A. Niyazov,[34] G. V. O'Rielly,[22] M. Osipenko,[16,23] A. I. Ostrovidov,[11] K. Park,[20] E. Pasyuk,[2] C. Peterson,[13] J. Pierce,[37] N. Pivnyuk,[18] D. Pocanic,[37] O. Pogorelko,[18] E. Polli,[15] S. Pozdniakov,[18] B. M. Preedom,[33] J. W. Price,[3] Y. Prok,[34] D. Protopopescu,[13] L. M. Qin,[27] B. A. Raue,[10,34] G. Riccardi,[11] G. Ricco,[16] M. Ripani,[16] B. G. Ritchie,[2] F. Ronchetti,[15] G. Rosner,[13] P. Rossi,[15] D. Rowntree,[21] P. D. Rubin,[32] F. Sabatié,[27,6] C. Salgado,[25] J. P. Santoro,[36,34] V. Sapunenko,[16,34] R. A. Schumacher,[4] V. S. Serov,[18] Y. G. Sharabian,[34] J. Shaw,[22] E. S. Smith,[34] L. C. Smith,[37] D. I. Sober,[5] A. Stavinsky,[18] S. Stepanyan,[34] B. E. Stokes,[11] P. Stoler,[30] S. Strauch,[33] R. Suleiman,[21] M. Taiuti,[16] S. Taylor,[31] D. J. Tedeschi,[33] R. Thompson,[29] A. Tkabladze,[27,26] S. Tkachenko,[27,26] L. Todor,[4] C. Tur,[33] M. Ungaro,[30,8] M. F. Vineyard,[35,32] A. V. Vlassov,[18] D. P. Weygand,[34] M. Williams,[4] E. Wolin,[34] M. H. Wood,[33] A. Yegneswaran,[34] J. Yun,[27] L. Zana,[24] and J. Zhang[27]

(CLAS Collaboration)

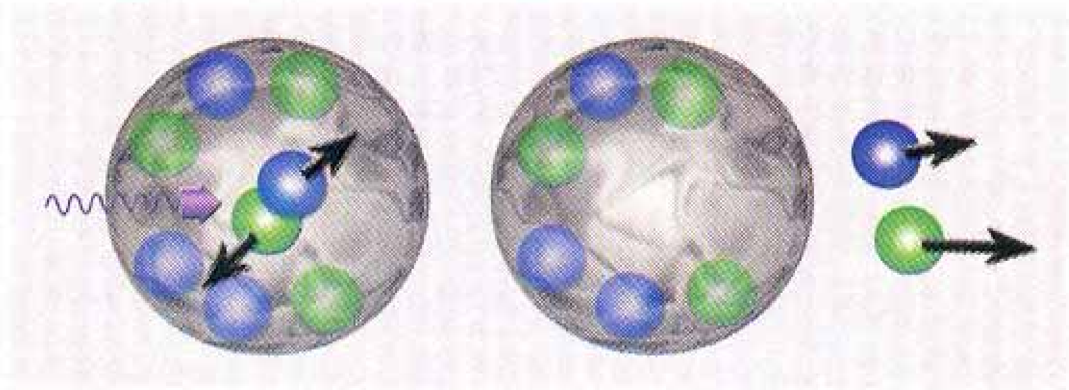


Fig. 1. Scattering of a virtual photon off a two-nucleon correlation, x > 1.5, before (left) and after (right) absorption of the photon.

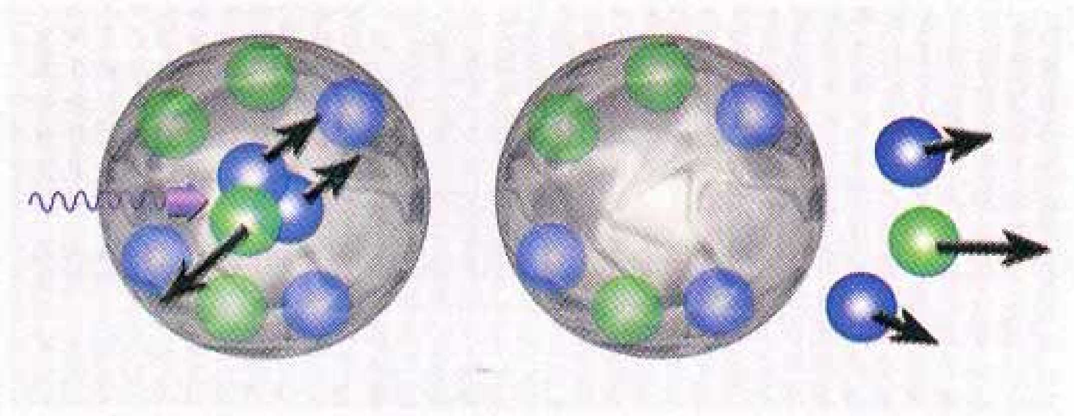
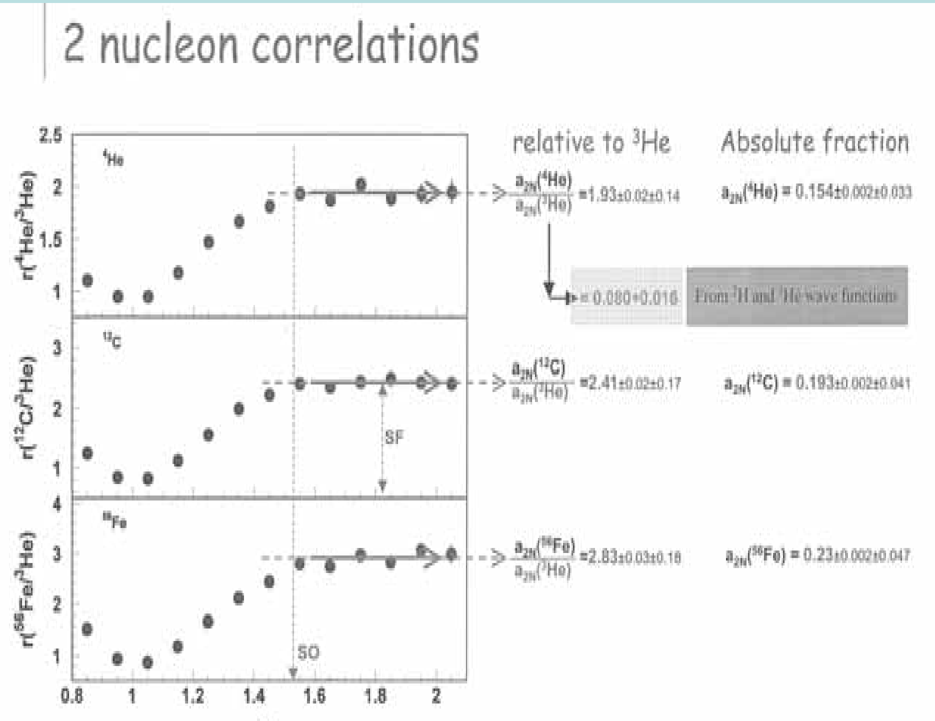


Fig. 2. Scattering of a virtual photon off a three-nucleon correlation, x > 2, before (left) and after (right) absorption of the photon.

JLAB data

A.Stavinskiy, ITEP seminar, 11.4.2007



2 nucleon correlations

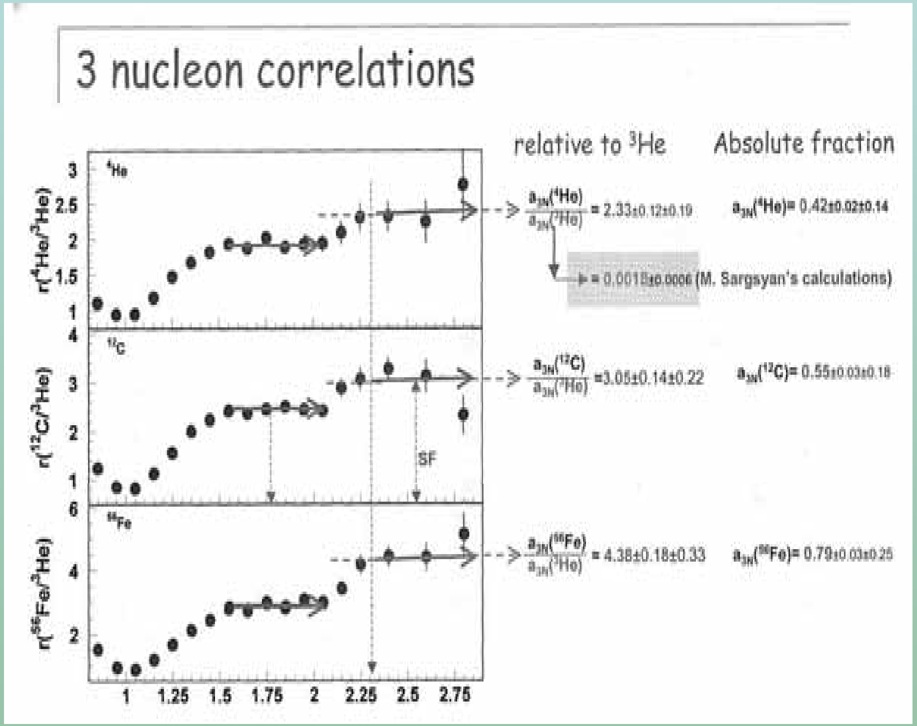
relative to ^{3}He | Absolute fraction

$\frac{a_{2N}(^4He)}{a_{2N}(^3He)} = 1.93\pm0.02\pm0.14$ $a_{2N}(^4He) = 0.154\pm0.002\pm0.033$

$= 0.080\pm0.016$ From ^{2}H and ^{3}He wave function

$\frac{a_{2N}(^{12}C)}{a_{2N}(^3He)} = 2.41\pm0.02\pm0.17$ $a_{2N}(^{12}C) = 0.193\pm0.002\pm0.041$

$\frac{a_{2N}(^{56}Fe)}{a_{2N}(^3He)} = 2.83\pm0.03\pm0.18$ $a_{2N}(^{56}Fe) = 0.23\pm0.002\pm0.047$



3 nucleon correlations

relative to ^{3}He | Absolute fraction

$\frac{a_{3N}(^4He)}{a_{3N}(^3He)} = 2.33\pm0.12\pm0.19$ $a_{3N}(^4He) = 0.42\pm0.02\pm0.14$

$= 0.0018\pm0.0006$ (M. Sargsyan's calculations)

$\frac{a_{3N}(^{12}C)}{a_{3N}(^3He)} = 3.05\pm0.14\pm0.22$ $a_{3N}(^{12}C) = 0.55\pm0.03\pm0.18$

$\frac{a_{3N}(^{56}Fe)}{a_{3N}(^3He)} = 4.38\pm0.18\pm0.33$ $a_{3N}(^{56}Fe) = 0.79\pm0.03\pm0.25$

JLAB data

JLAB Phys Seminar Dec05 K. Egiyan

Having these data, we know almost full (≈99%) nucleonic picture of nuclei with $A \leq 56$

Fractions **Nucleus**	Single particle (%)	2N SRC (%)	3N SRC (%)
^{56}Fe	**76** ± 0.2 ± 4.7	**23.0** ± 0.2 ± 4.7	**0.79** ± 0.03 ± 0.25
^{12}C	**80** ± 02 ± 4.1	**19.3** ± 0.2 ± 4.1	**0.55** ± 0.03 ± 0.18
^{4}He	**86** ± 0.2 ± 3.3	**15.4** ± 0.2 ± 3.3	**0.42** ± 0.02 ± 0.14
^{3}He	**92** ± 1.6	**8.0** ± 1.6	**0.18** ± 0.06
^{2}H	**96** ± 0.8	**4.0** ± 0.8	-----

Using the published data on (p,2p+n) [PRL,90 (2003) 042301] estimate the isotopic composition of 2N SRC in ^{12}C

$$a_{2N}(^{12}C) \approx 20 \pm 0.2 \pm 4.1\ \% \;\longrightarrow\; \begin{aligned} a_{pp}(^{12}C) &\approx 4 \pm 2\ \% \\ a_{pn}(^{12}C) &\approx 12 \pm 4\ \% \\ a_{nn}(^{12}C) &\approx 4 \pm 2\ \% \end{aligned}$$

Cumulative (subthreshold) particle production are very nice processes to investigate the high dense state of the cold nuclear matter.

Two theoretical ways to describe these phenomena:

- Fluctons will open new possibilities

- Fermi motion and SRC

(quark stars, diquark condensate...)

The main questions

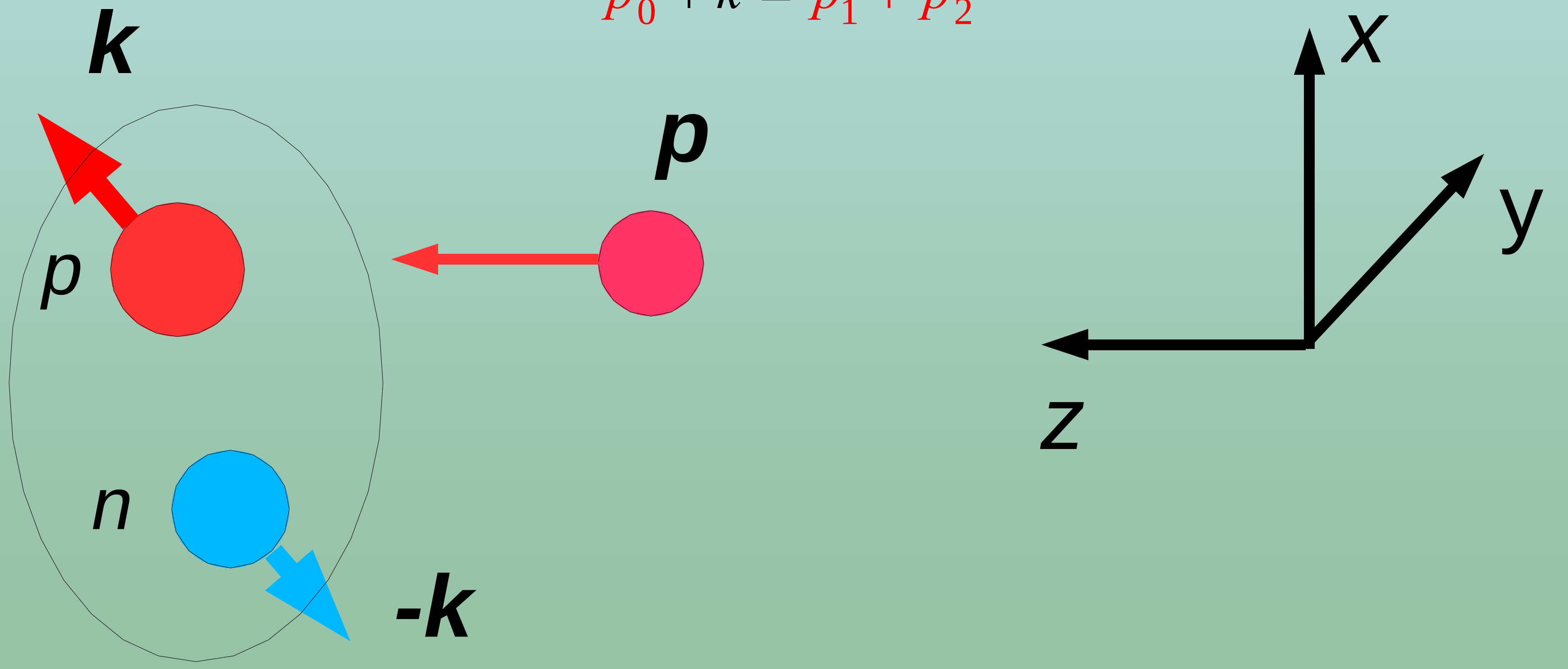
Do we see multiquark states inside nuclei or it's SRC of nucleons?

Which properties of these objects?

High p_T road (E850/EVA)

$$p + "D"$$

$$\overline{p}_0 + \overline{k} = \overline{p}_1 + \overline{p}_2$$



E850/EVA (BNL)

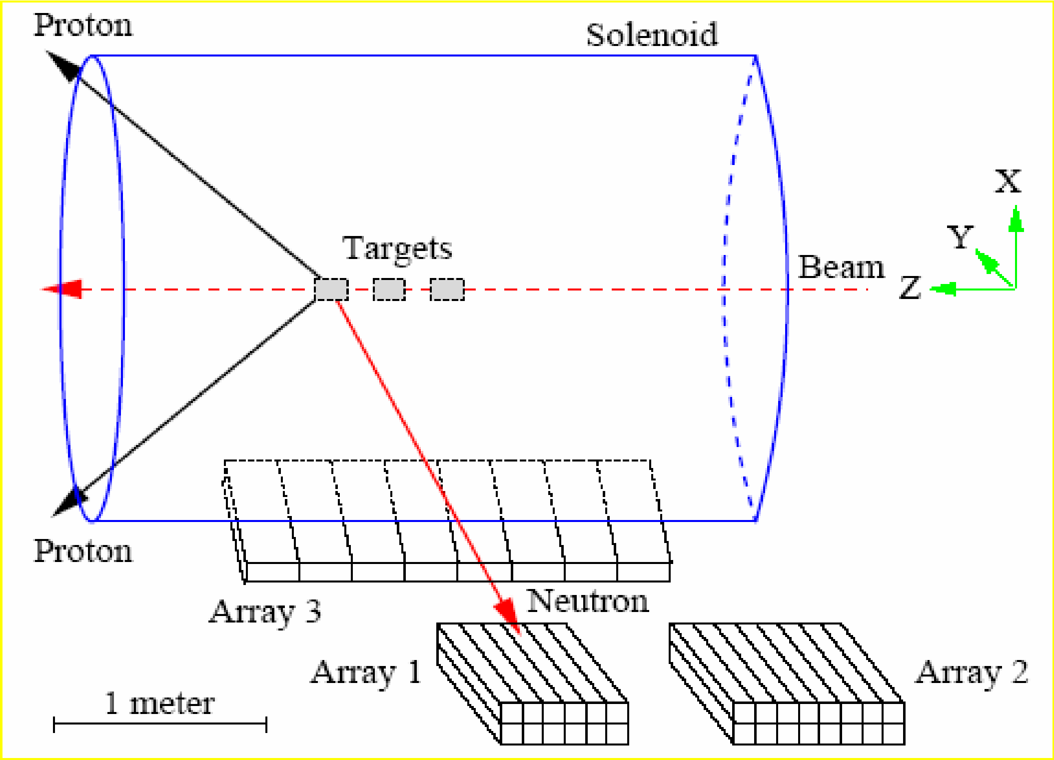
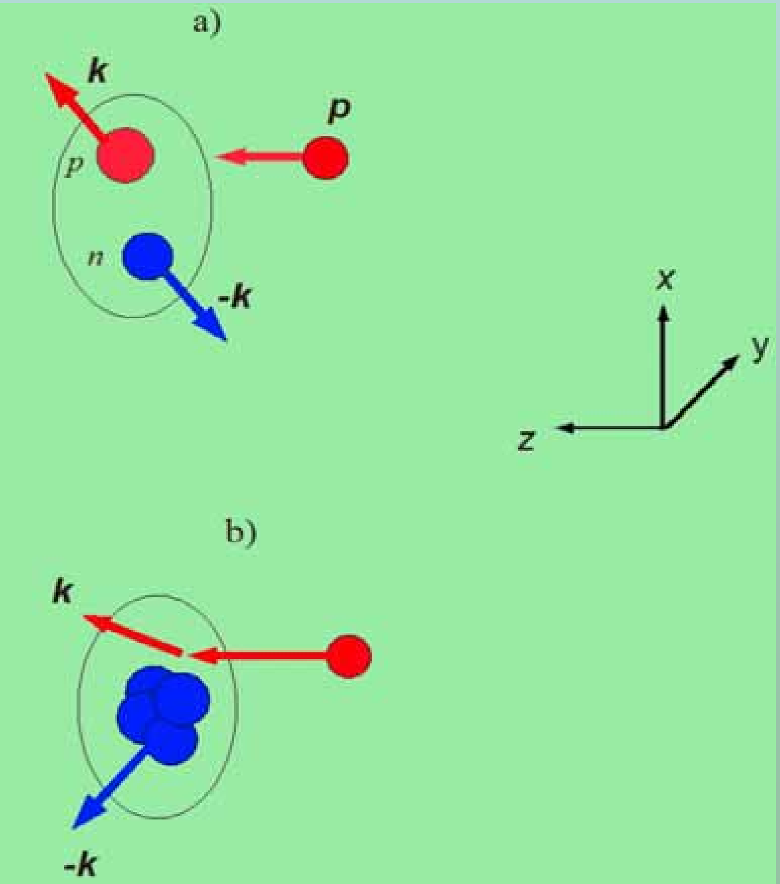
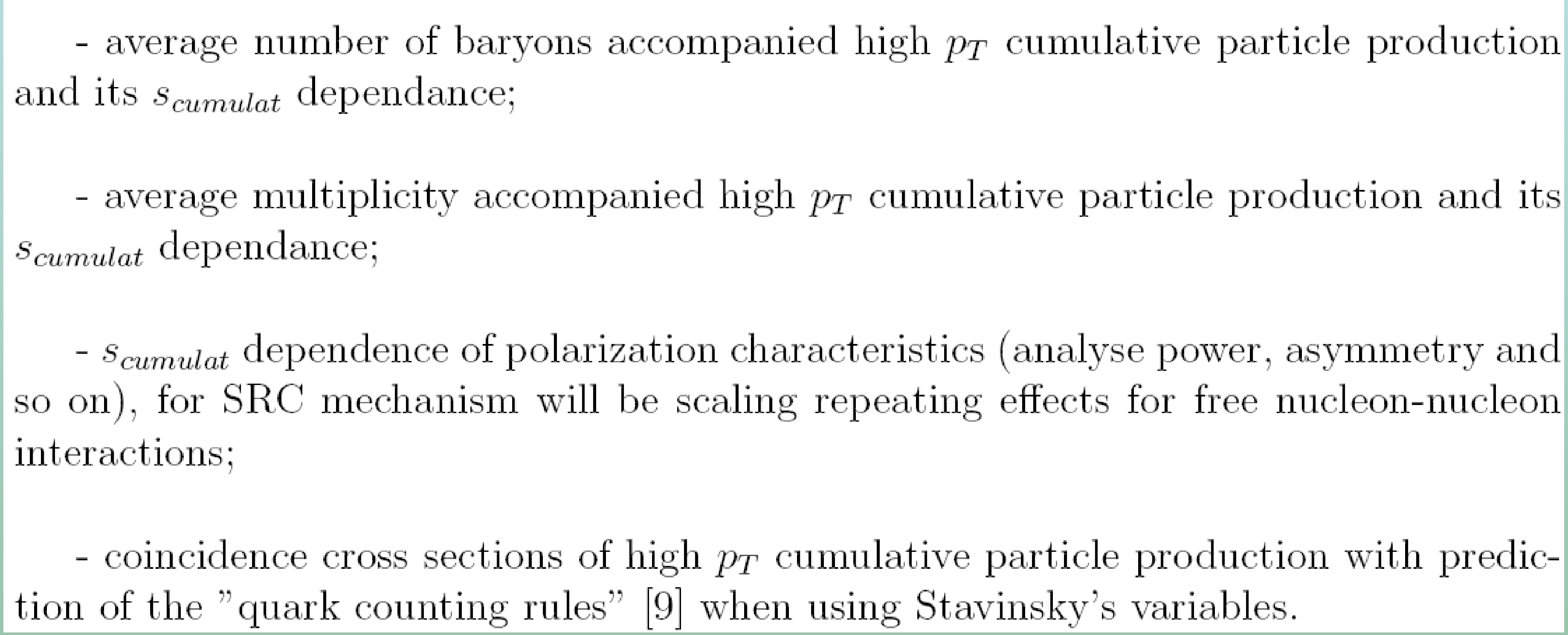


Figure I.3: A schematic view of the EVA solenoid and the neutron counters in the 1998 measurement.

We need more complete investigation in the range of maximal p_T in semi-exclusive (and exclusive) experiment setup for comprehension of the nature of cumulative processes and CT.



S.S. RNP 2005 Proceedings
nucl-ex/0604014



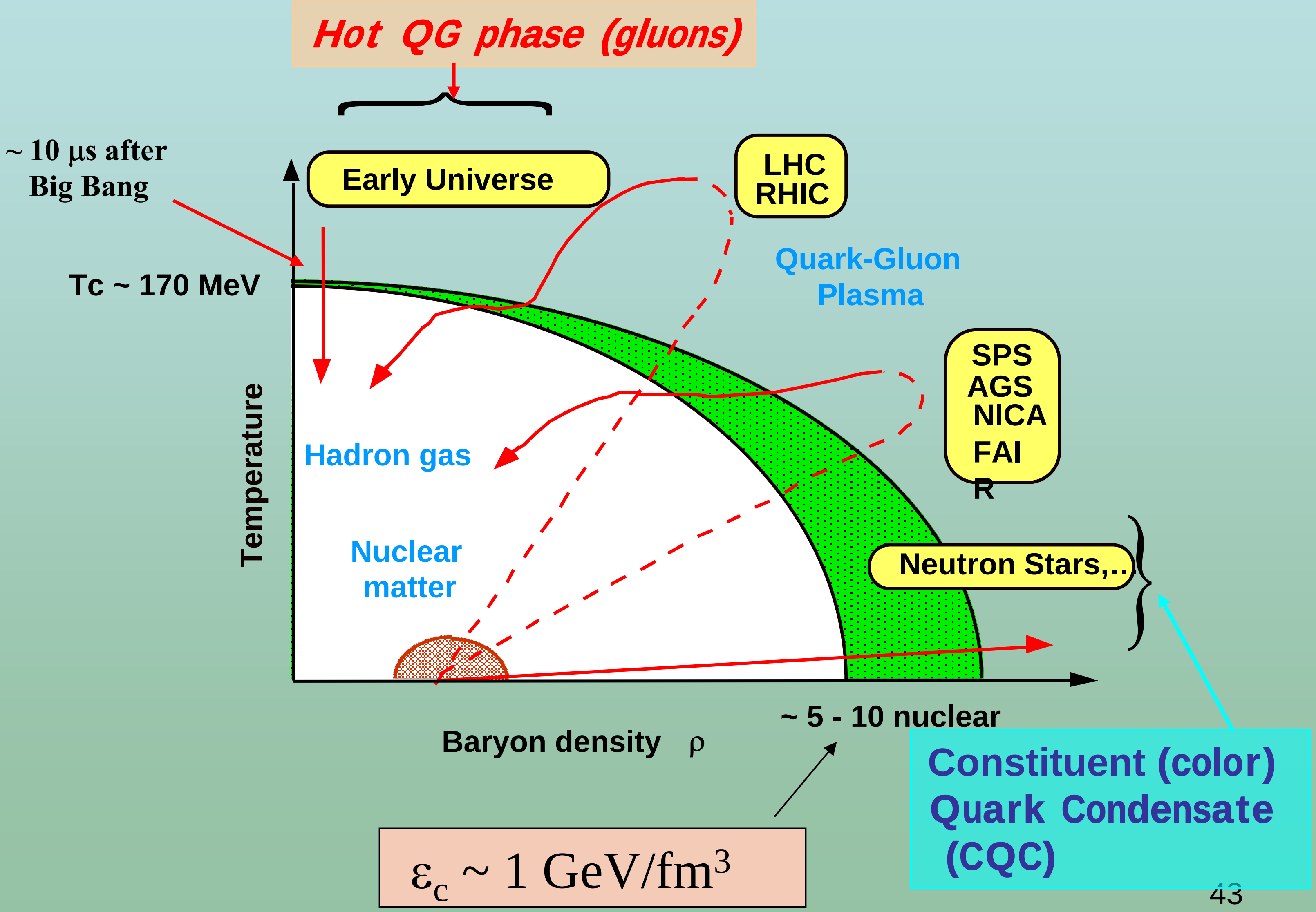
- average number of baryons accompanied high p_T cumulative particle production and its $s_{cumulat}$ dependance;

- average multiplicity accompanied high p_T cumulative particle production and its $s_{cumulat}$ dependance;

- $s_{cumulat}$ dependence of polarization characteristics (analyse power, asymmetry and so on), for SRC mechanism will be scaling repeating effects for free nucleon-nucleon interactions;

- coincidence cross sections of high p_T cumulative particle production with prediction of the "quark counting rules" [9] when using Stavinsky's variables.

QCD phase diagram



Hot QG phase (gluons)

~ 10 μs after Big Bang

Early Universe

LHC RHIC

Quark-Gluon Plasma

Tc ~ 170 MeV

SPS AGS NICA FAIR

Temperature

Hadron gas

Nuclear matter

Neutron Stars,..

Baryon density ρ

~ 5 - 10 nuclear

$\varepsilon_c \sim 1\ \mathrm{GeV/fm}^3$

Constituent (color) Quark Condensate (CQC)

Shimanskiy S.S.

Strangeness in Neutron Stars

FRIDOLIN WEBER[*], ALEXANDER HO[†], RODRIGO P. NEGREIROS[‡], PHILIP ROSENFIELD[§]

astro-ph/0604422 v1 20 Apr 2006

H ~ 10^{17} Gs

E~ 10^{19} V/cm

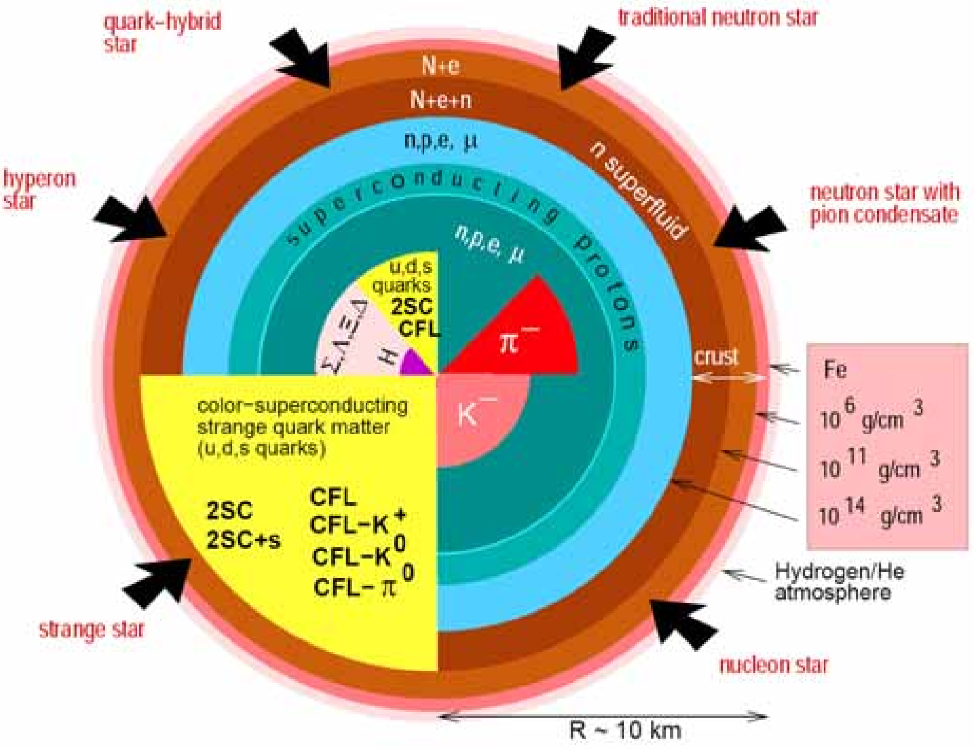


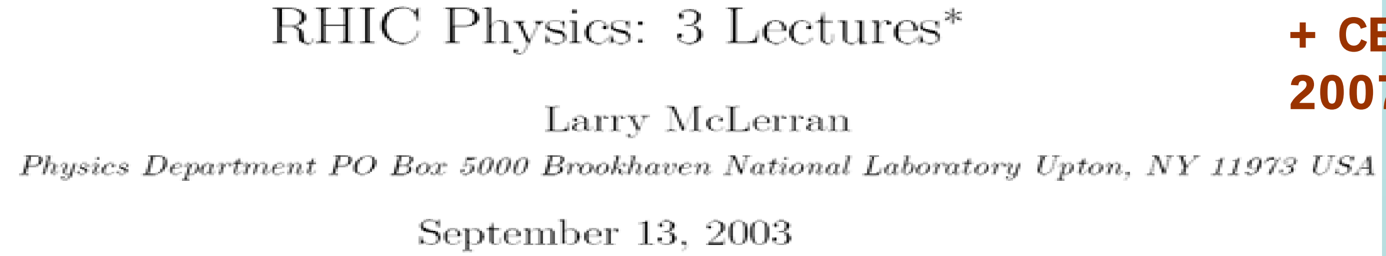
Fig. 1. Competing structures and novel phases of subatomic matter predicted by theory to make their appearances in the cores ($R \lesssim 8$ km) of neutron stars[4].

significant range of chemical potentials and strange quark masses[51]. If the strange quark mass is heavy enough to be ignored, then up and down quarks may pair in the two-flavor superconducting (2SC) phase. Other possible condensation patters

K. Rajagopal and F. Wilczek, *The Condensed Matter Physics of QCD*, At the Frontier of Particle Physics / Handbook of QCD, ed. M. Shifman, (World Scientific) (2001). M. Alford, Ann. Rev. Nucl. Part. Sci. **51** (2001) 131.

color−superconducting strange quark matter (u,d,s quarks)

Shimanskiy S.S.



RHIC Physics: 3 Lectures*

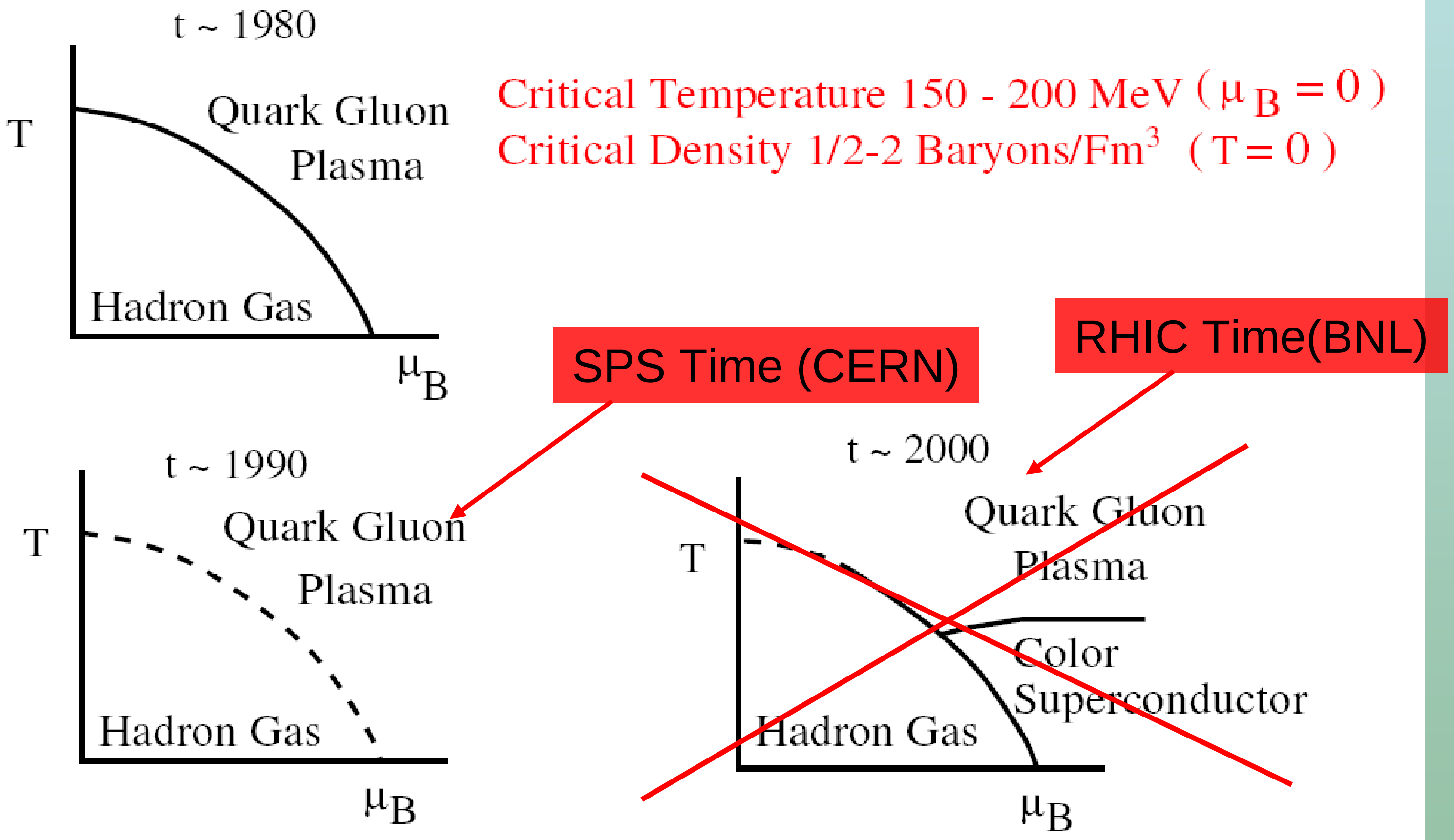
Larry McLerran

Physics Department PO Box 5000 Brookhaven National Laboratory Upton, NY 11973 USA

September 13, 2003

+ CERN Yellow Report 2007-005, p.75

The Evolving QCD Phase Transition



Critical Temperature 150 - 200 MeV ($\mu_B = 0$)

Critical Density 1/2-2 Baryons/Fm^3 ($T = 0$)

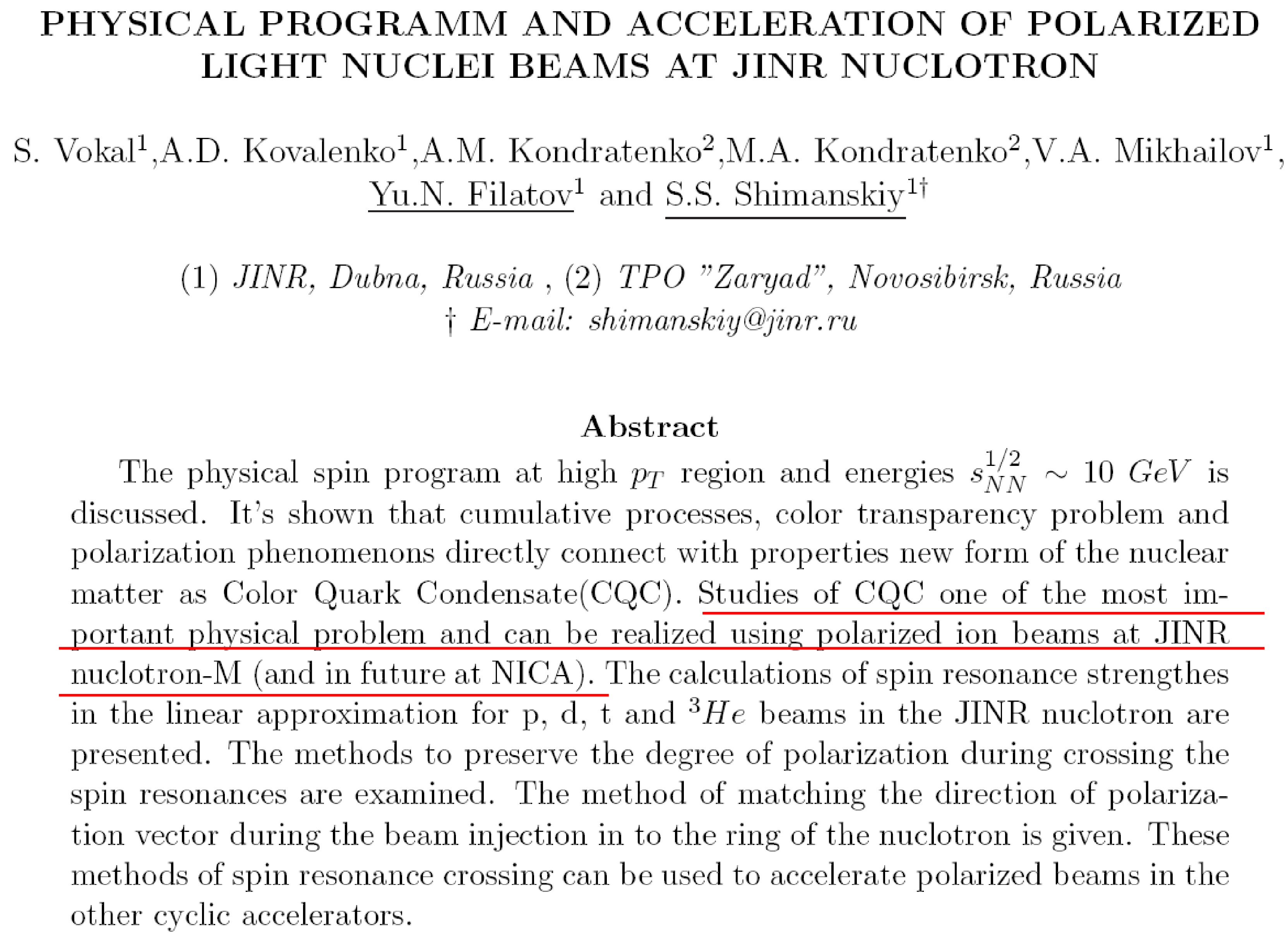
SPS Time (CERN)

RHIC Time(BNL)

Figure 4: A phase diagram for QCD collisions.

Proceeding DSPIN`07, p.409, Dubna 2008

arXiv:0802.4153v1 [hep-ex] 28 Feb 2008



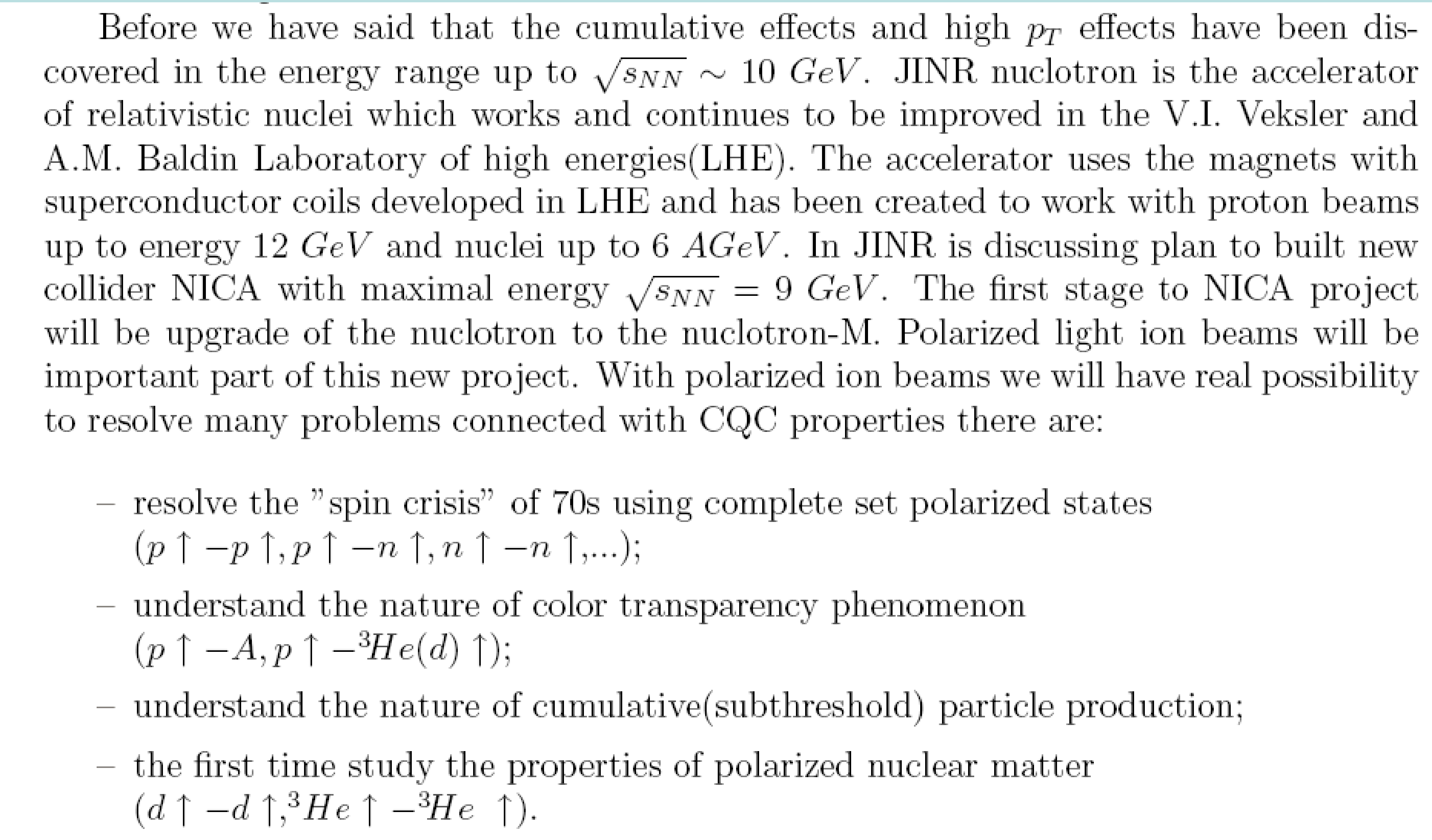
PHYSICAL PROGRAMM AND ACCELERATION OF POLARIZED LIGHT NUCLEI BEAMS AT JINR NUCLOTRON

S. Vokal[1],A.D. Kovalenko[1],A.M. Kondratenko[2],M.A. Kondratenko[2],V.A. Mikhailov[1],
Yu.N. Filatov[1] and S.S. Shimanskiy[1†]

(1) *JINR, Dubna, Russia* , (2) *TPO "Zaryad", Novosibirsk, Russia*
† *E-mail: shimanskiy@jinr.ru*

Abstract

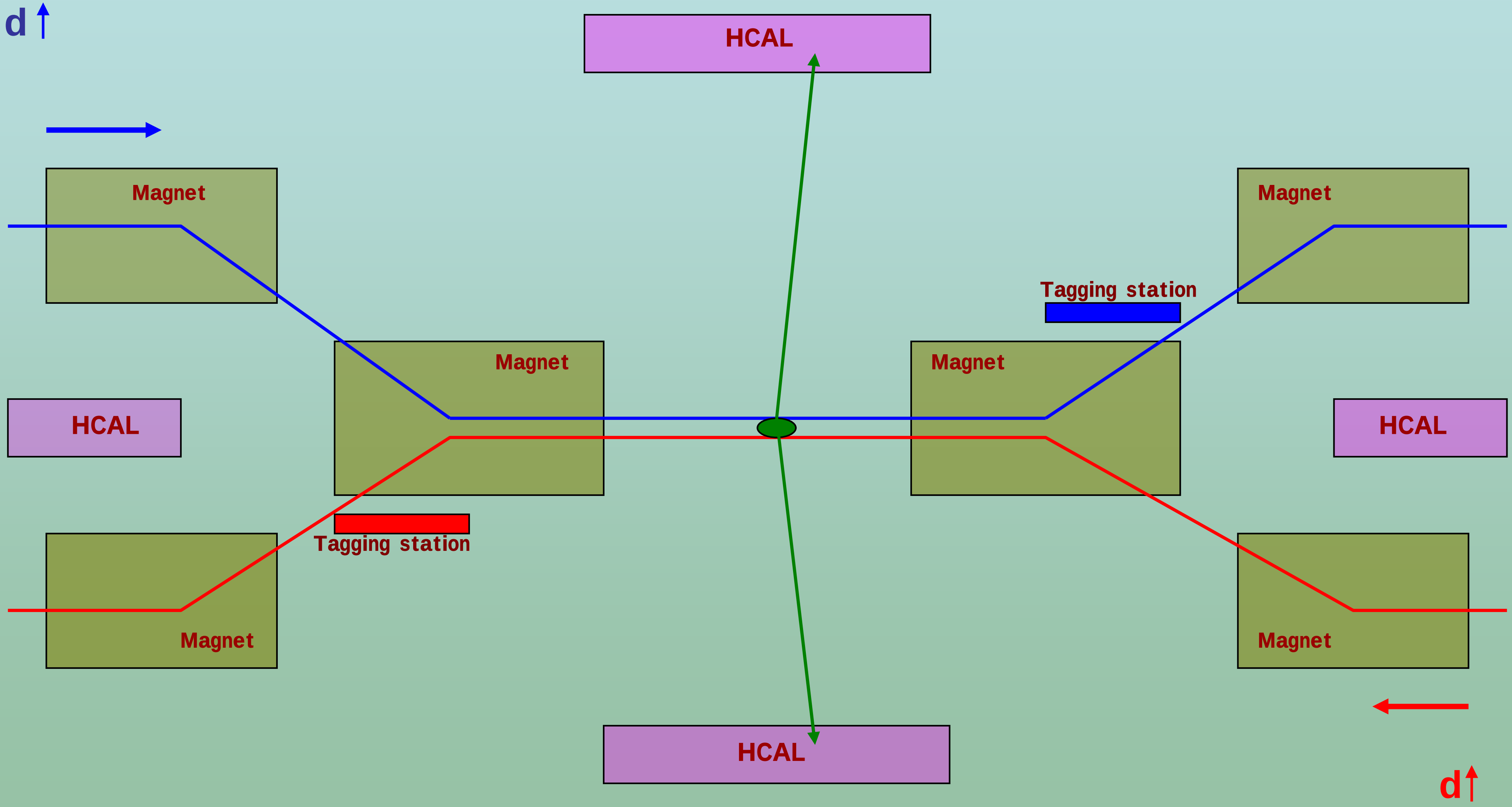
The physical spin program at high p_T region and energies $s_{NN}^{1/2} \sim 10\ GeV$ is discussed. It's shown that cumulative processes, color transparency problem and polarization phenomenons directly connect with properties new form of the nuclear matter as Color Quark Condensate(CQC). Studies of CQC one of the most important physical problem and can be realized using polarized ion beams at JINR nuclotron-M (and in future at NICA). The calculations of spin resonance strengthes in the linear approximation for p, d, t and ^3He beams in the JINR nuclotron are presented. The methods to preserve the degree of polarization during crossing the spin resonances are examined. The method of matching the direction of polarization vector during the beam injection in to the ring of the nuclotron is given. These methods of spin resonance crossing can be used to accelerate polarized beams in the other cyclic accelerators.



Before we have said that the cumulative effects and high p_T effects have been discovered in the energy range up to $\sqrt{s_{NN}} \sim 10\ GeV$. JINR nuclotron is the accelerator of relativistic nuclei which works and continues to be improved in the V.I. Veksler and A.M. Baldin Laboratory of high energies(LHE). The accelerator uses the magnets with superconductor coils developed in LHE and has been created to work with proton beams up to energy 12 GeV and nuclei up to 6 $AGeV$. In JINR is discussing plan to built new collider NICA with maximal energy $\sqrt{s_{NN}} = 9\ GeV$. The first stage to NICA project will be upgrade of the nuclotron to the nuclotron-M. Polarized light ion beams will be important part of this new project. With polarized ion beams we will have real possibility to resolve many problems connected with CQC properties there are:

- resolve the "spin crisis" of 70s using complete set polarized states $(p\uparrow - p\uparrow, p\uparrow - n\uparrow, n\uparrow - n\uparrow, ...)$;
- understand the nature of color transparency phenomenon $(p\uparrow - A, p\uparrow - {}^3He(d)\uparrow)$;
- understand the nature of cumulative(subthreshold) particle production;
- the first time study the properties of polarized nuclear matter $(d\uparrow - d\uparrow, {}^3He\uparrow - {}^3He\ \uparrow)$.

NICA Collision place for SPIN physics (deuteron beams example)



Shimanskiy S.S.

“spin crisis” of 70’s

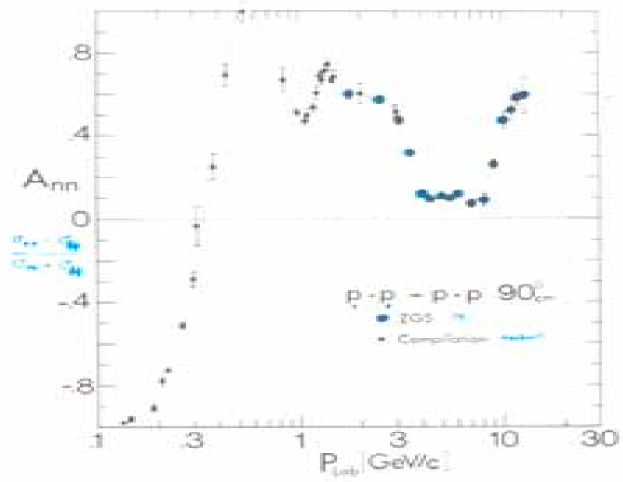


Figure 4: A_{nn} is plotted against P_{Lab}.

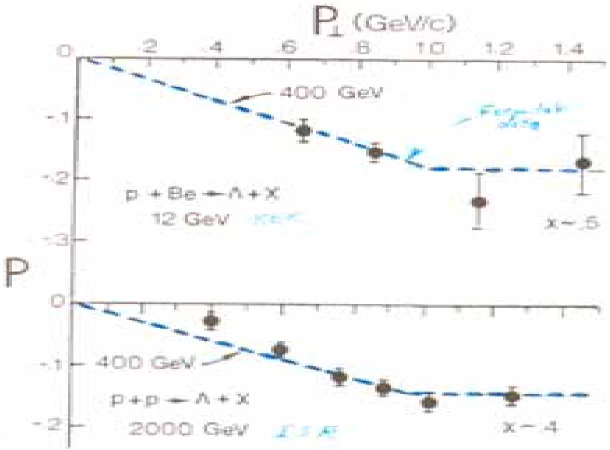


Figure 6: The Λ polarization is plotted against $P_\perp^2$.

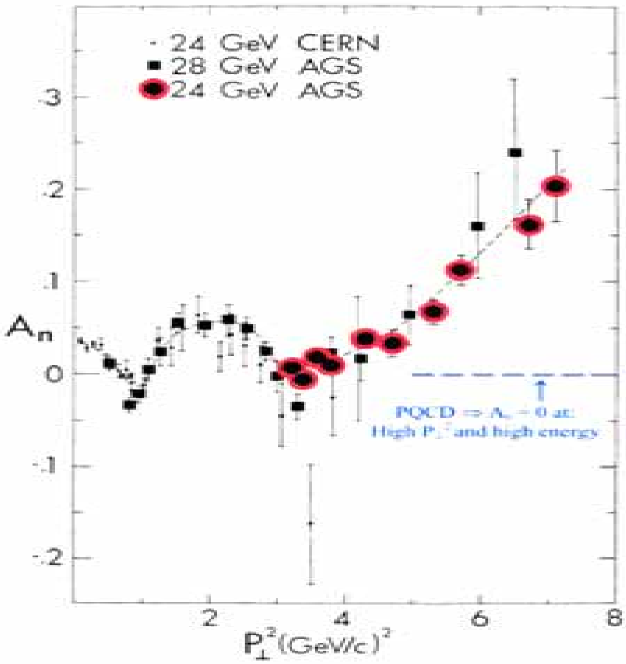


Figure 5: A_n is plotted against $P_\perp^2$.

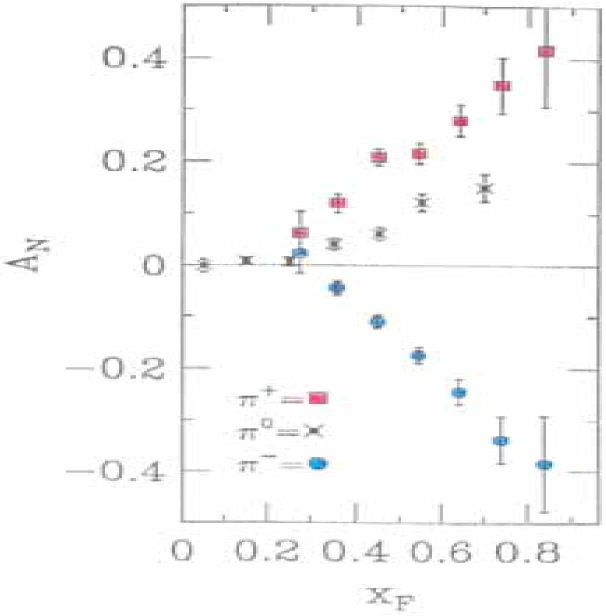
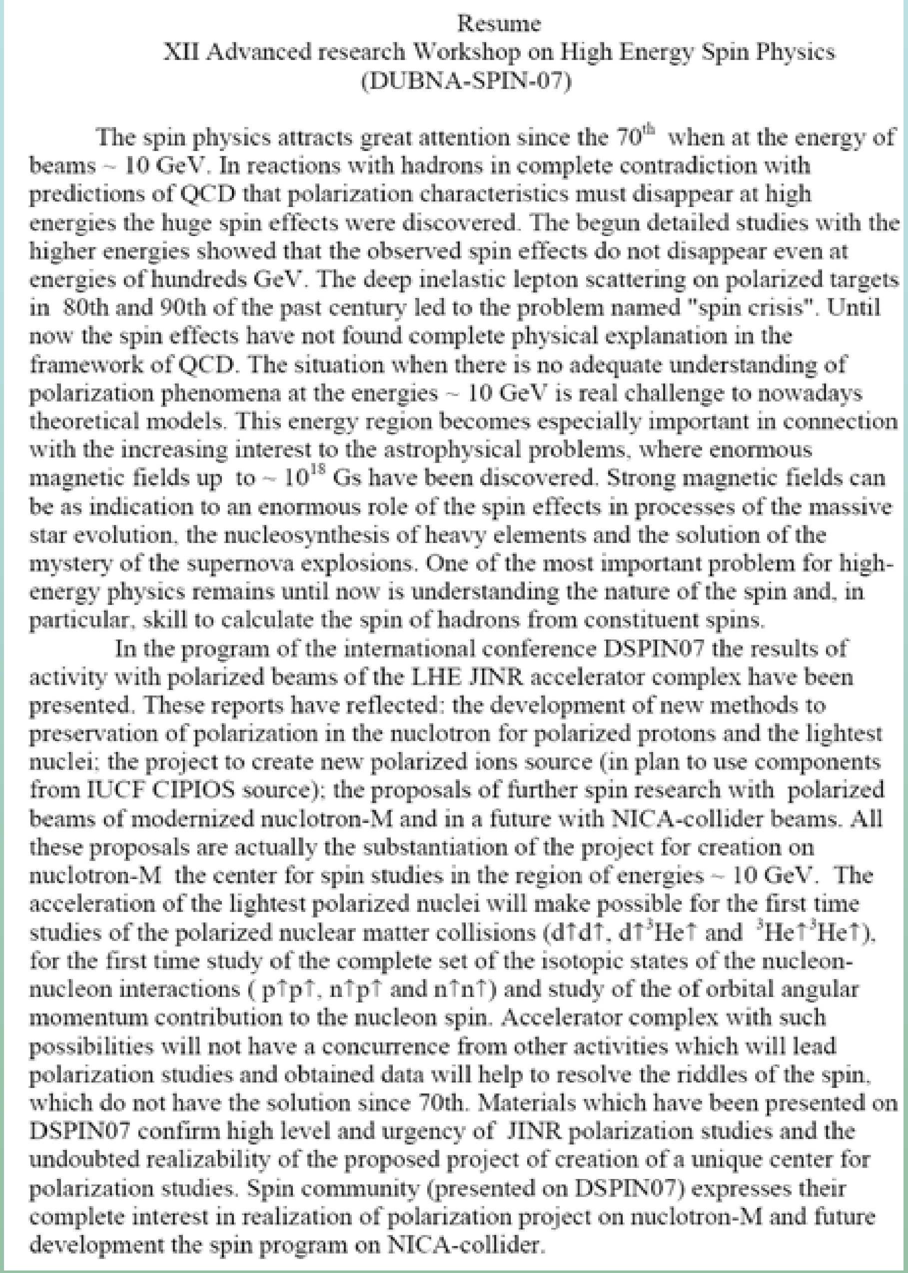


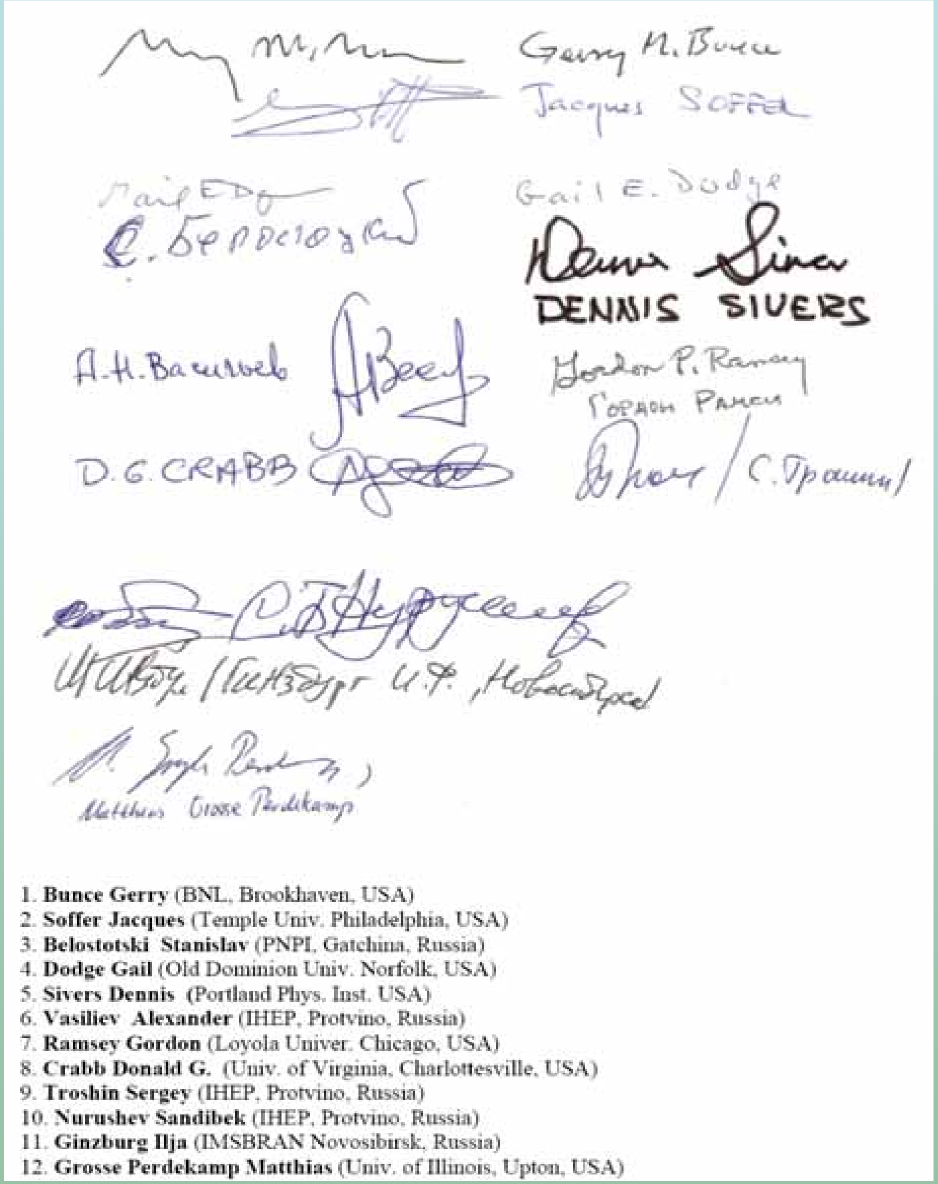
Figure 7: A_N is plotted against X_F for inclusive π-meson production.



Resume
XII Advanced research Workshop on High Energy Spin Physics
(DUBNA-SPIN-07)

The spin physics attracts great attention since the 70th when at the energy of beams ~ 10 GeV. In reactions with hadrons in complete contradiction with predictions of QCD that polarization characteristics must disappear at high energies the huge spin effects were discovered. The begun detailed studies with the higher energies showed that the observed spin effects do not disappear even at energies of hundreds GeV. The deep inelastic lepton scattering on polarized targets in 80th and 90th of the past century led to the problem named "spin crisis". Until now the spin effects have not found complete physical explanation in the framework of QCD. The situation when there is no adequate understanding of polarization phenomena at the energies ~ 10 GeV is real challenge to nowadays theoretical models. This energy region becomes especially important in connection with the increasing interest to the astrophysical problems, where enormous magnetic fields up to ~ 10^{18} Gs have been discovered. Strong magnetic fields can be as indication to an enormous role of the spin effects in processes of the massive star evolution, the nucleosynthesis of heavy elements and the solution of the mystery of the supernova explosions. One of the most important problem for high-energy physics remains until now is understanding the nature of the spin and, in particular, skill to calculate the spin of hadrons from constituent spins.

In the program of the international conference DSPIN07 the results of activity with polarized beams of the LHE JINR accelerator complex have been presented. These reports have reflected: the development of new methods to preservation of polarization in the nuclotron for polarized protons and the lightest nuclei; the project to create new polarized ions source (in plan to use components from IUCF CIPIOS source); the proposals of further spin research with polarized beams of modernized nuclotron-M and in a future with NICA-collider beams. All these proposals are actually the substantiation of the project for creation on nuclotron-M the center for spin studies in the region of energies ~ 10 GeV. The acceleration of the lightest polarized nuclei will make possible for the first time studies of the polarized nuclear matter collisions ($d\uparrow d\uparrow$, $d\uparrow{}^3He\uparrow$ and ${}^3He\uparrow{}^3He\uparrow$), for the first time study of the complete set of the isotopic states of the nucleon-nucleon interactions ($p\uparrow p\uparrow$, $n\uparrow p\uparrow$ and $n\uparrow n\uparrow$) and study of the of orbital angular momentum contribution to the nucleon spin. Accelerator complex with such possibilities will not have a concurrence from other activities which will lead polarization studies and obtained data will help to resolve the riddles of the spin, which do not have the solution since 70th. Materials which have been presented on DSPIN07 confirm high level and urgency of JINR polarization studies and the undoubted realizability of the proposed project of creation of a unique center for polarization studies. Spin community (presented on DSPIN07) expresses their complete interest in realization of polarization project on nuclotron-M and future development the spin program on NICA-collider.



Gerry M. Bunce
Jacques SOFFER
С. Белостоцкий
Gail E. Dodge
DENNIS SIVERS
А.Н. Васильев
Gordon P. Ramsey
Гордон Рамси
D.G. CRABB
С. Трошин
(Гинзбург И.Ф., Новосибирск)
Matthias Grosse Perdekamp

1. **Bunce Gerry** (BNL, Brookhaven, USA)
2. **Soffer Jacques** (Temple Univ. Philadelphia, USA)
3. **Belostotski Stanislav** (PNPI, Gatchina, Russia)
4. **Dodge Gail** (Old Dominion Univ. Norfolk, USA)
5. **Sivers Dennis** (Portland Phys. Inst. USA)
6. **Vasiliev Alexander** (IHEP, Protvino, Russia)
7. **Ramsey Gordon** (Loyola Univer. Chicago, USA)
8. **Crabb Donald G.** (Univ. of Virginia, Charlottesville, USA)
9. **Troshin Sergey** (IHEP, Protvino, Russia)
10. **Nurushev Sandibek** (IHEP, Protvino, Russia)
11. **Ginzburg Ilja** (IMSBRAN Novosibirsk, Russia)
12. **Grosse Perdekamp Matthias** (Univ. of Illinois, Upton, USA)

THANK YOU FOR ATTANTION!