Секция ядерной физики ОФН РАН
Объединённый институт ядерных исследований

НАУЧНАЯ СЕССИЯ СЕКЦИИ ЯДЕРНОЙ ФИЗИКИ ОТДЕЛЕНИЯ ФИЗИЧЕСКИХ НАУК РАН,

посвящённая 300-летию Российской академии наук

"The high transverse momenta (p_T > 1 GeV/c) physics and problems of non-perturbative QCD"

S.S. Shimanskiy (JINR)

Новые возможности – новые детекторы

“New directions in science are launched by new tools much more often than by new concepts.

Новые направления в науке запускаются новыми инструментами(методиками) гораздо чаще, чем новыми концепциями.

The effect of a concept-driven revolution is to explain old things in new ways.

Эффект концептуальной революции состоит в том, чтобы объяснить старые вещи по-новому. *(нужны новые модели и теории)*

The effect of a tool-driven revolution is to discover new things that have to be explained”

Эффект инструментальной революции заключается в открытии новых вещей, которые должны быть объяснены. *(нужны новые детекторы).*

From Freeman Dyson ‘Imagined Worlds’

А.М. Балдин

Уникальная энергетическая область, где происходит переход от адронных к кварк-глюонным степеням свободы.
Область где доминируют законы непертурбативные КХД (которые мы не понимаем) и наблюдается большое число эффектов, не имеющих десятилетия физического даже качественного объяснения.
Мы имеем возможность понять законы непертурбативной КХД и объяснить многие загадки.

Там где не работают пертурбативная КХД и партонная модель.

PHYSICAL REVIEW VOLUME 126, NUMBER 5 JUNE 1, 1962

Particle Production at Large Angles by 30- and 33-Bev Protons Incident on Aluminum and Beryllium*

V. L. Fitch, S. L. Meyer,† and P. A. Piroué
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey

(Received February 12, 1962)

+ d/p problem, cum. Region ~0.25

p/π ratio ~ 20

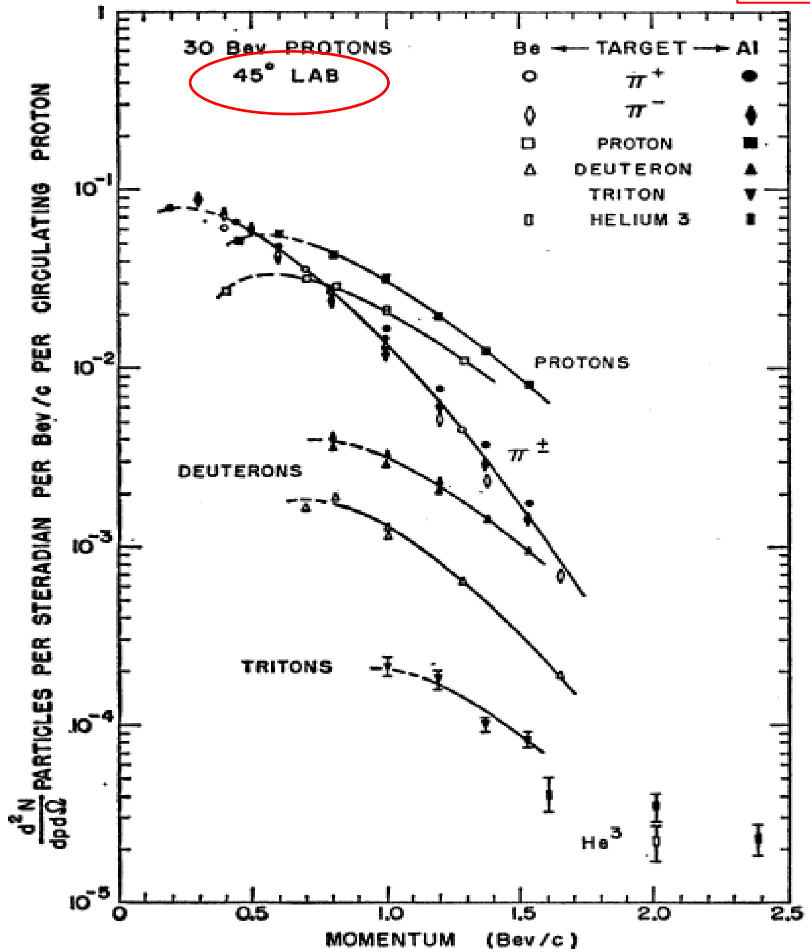


Fig. 3. Momentum spectra of particles emitted at 45° from aluminum and beryllium targets when struck by 30-Bev protons. Tritons from Be were not measured. For general remarks refer to Fig. 2 caption.

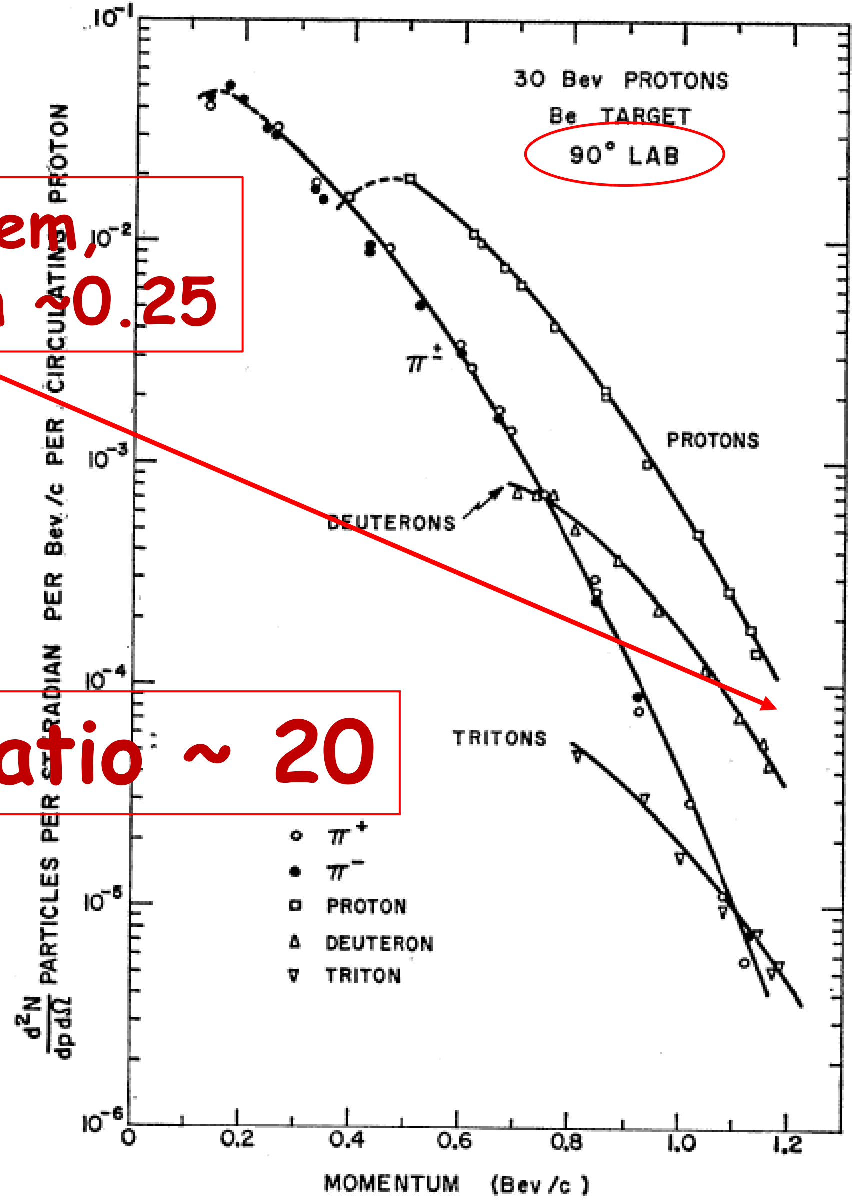


Fig. 2. Momentum spectrum of particles emitted at 90° from a beryllium target struck by 30-Bev protons. The ordinate is the number of particles produced at the target per steradian per Bev/c per circulating proton. The dashed portions of the curves indicate regions where the corrections due to multiple scattering exceed 15%. At the time these data were taken no effort was made to detect He³.

VOLUME 5, NUMBER 1 PHYSICAL REVIEW LETTERS JULY 1, 1960

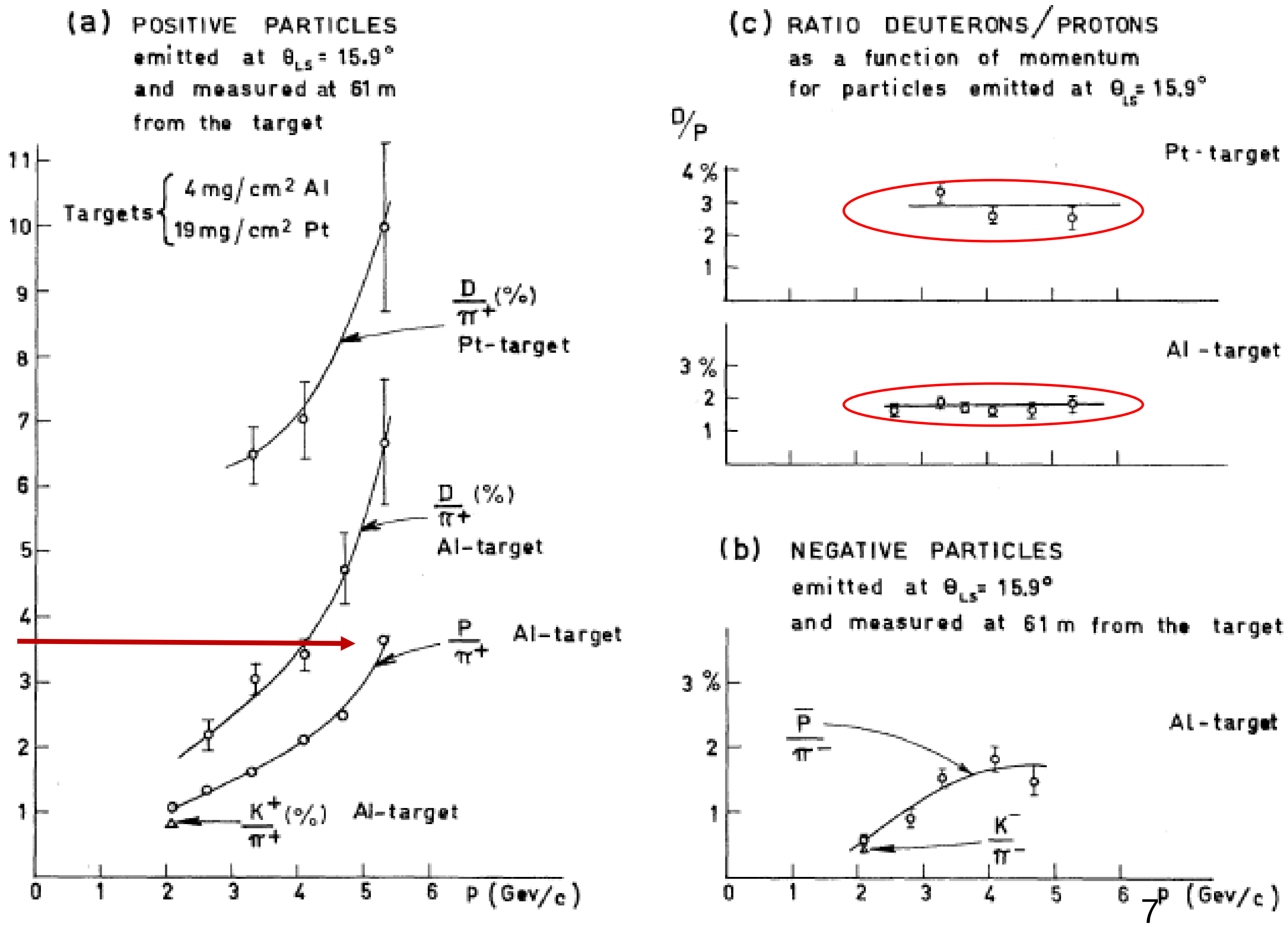
MASS ANALYSIS OF THE SECONDARY PARTICLES PRODUCED BY THE 25-GEV PROTON BEAM OF THE CERN PROTON SYNCHROTRON

V. T. Cocconi,* T. Fazzini, G. Fidecaro, M. Legros,† N. H. Lipman, and A. W. Merrison
CERN, Geneva, Switzerland
(Received June 1, 1960)

We present here some results of a mass analysis of the secondary particles produced at 15.9° to the circulating beam in an aluminum target bombarded by 25-Gev protons in the CERN proto synchrotron.

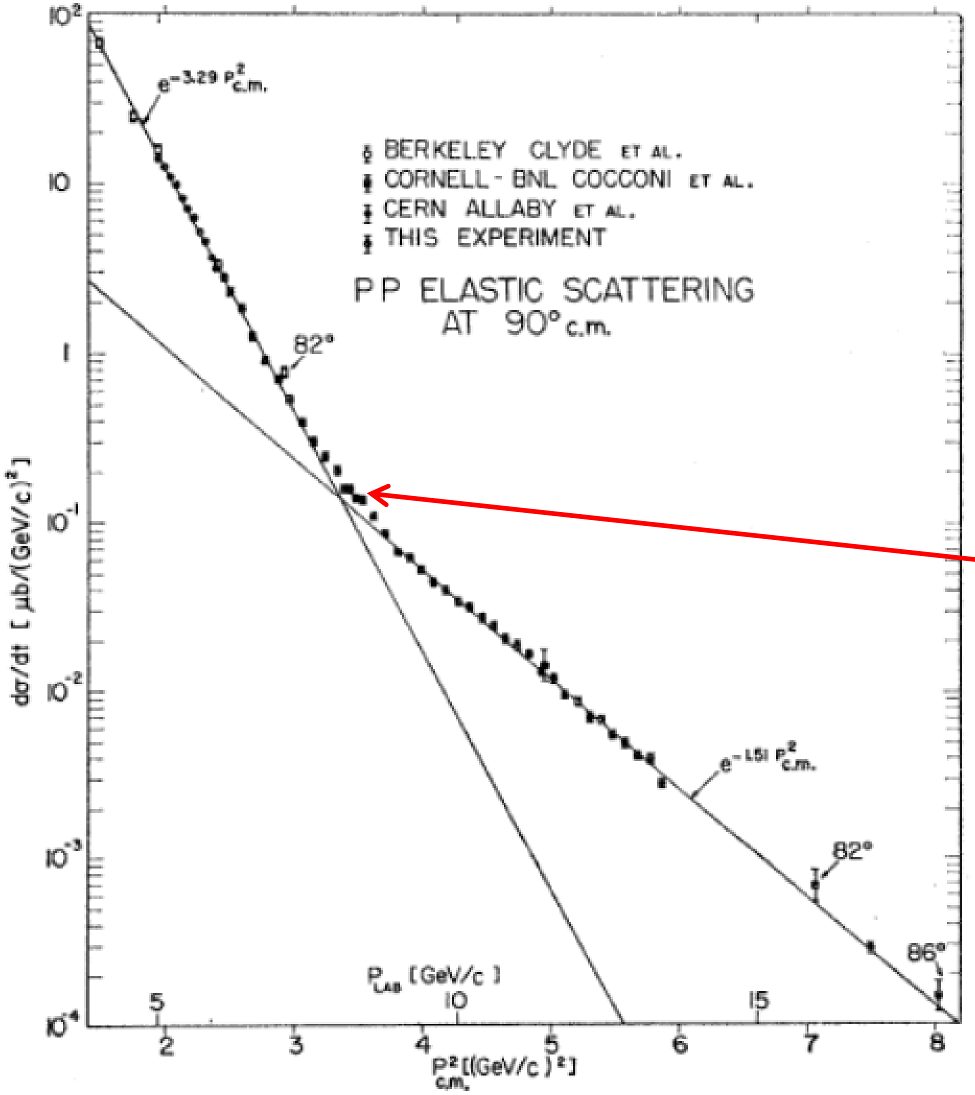
D/p ratio

p/π ratio



pp -> pp (90^0)

C.W. Akerlof et al., Phys.Rev., vol.159, N5, 1138-1149, 1967

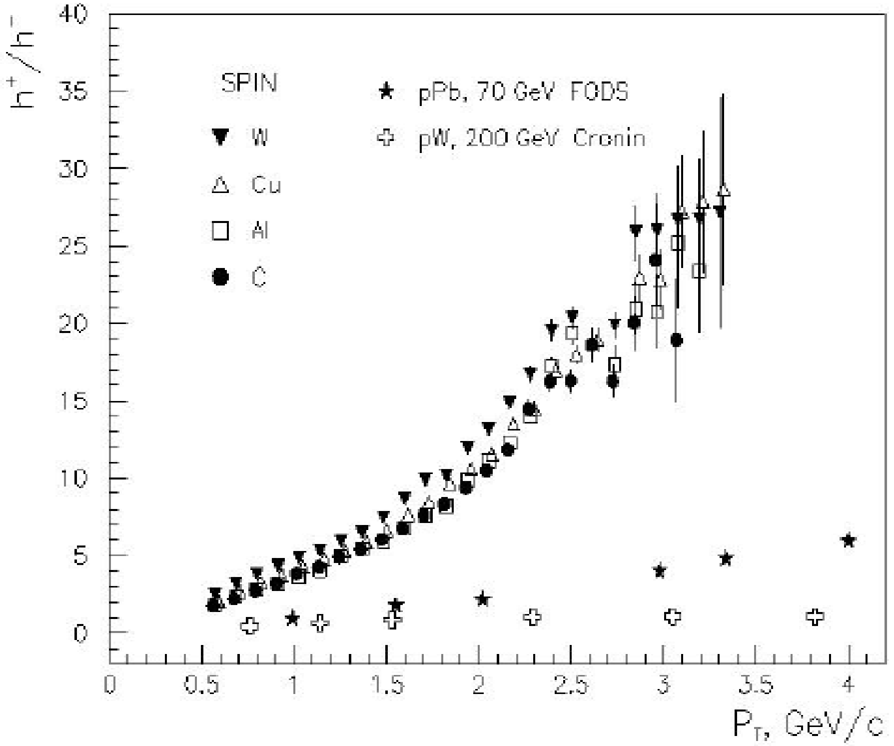


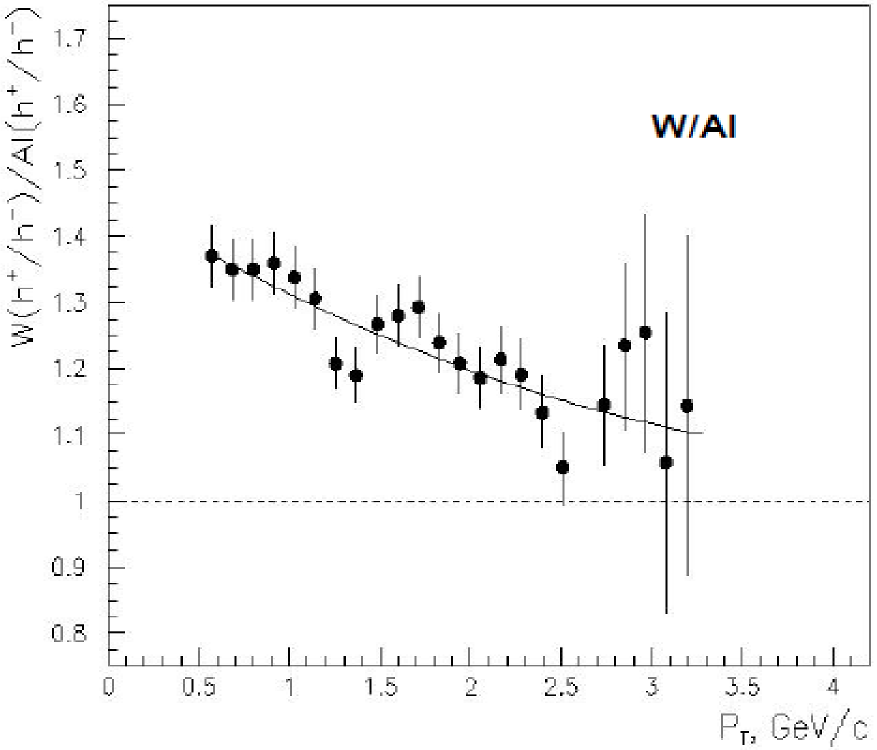
Krisch A. and Leksin G. – non pointlike structure of nucleon

p_T ~ 2 GeV/c

SPIN data

Отношение h^+/h^-





- С ростом поперечного импульса наблюдается значительно больший выход h+ по отношению к h-.
- Отсутствие сильной зависимости h+/h - от атомного числа при больших P_T может рассматриваться как указанием на локальный механизм образования частиц и малый вклад процессов вторичного взаимодействия

J.W. Cronin et al., Production of hadrons at large transverse momentum at 200, 300, and 400 GeV, Phys.Rev. D, v.11, N 11, 3105-3123 (1975)

p_T ~ 2 GeV/c region

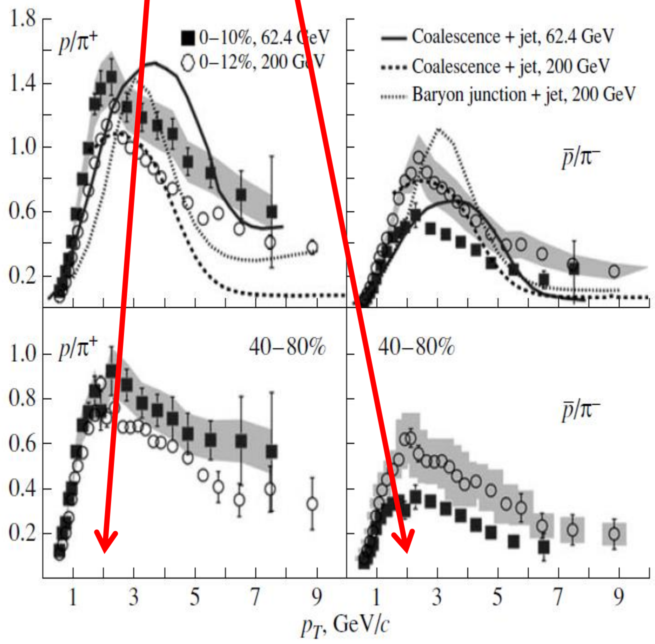


Fig. 3. [10] Ratio of the cross sections for the production of protons and charged pions as a function of the transverse momentum for various degrees of centrality and two beam energies of 62.4 and 200 GeV: (points) results of the STAR experiment and (curves) results of model calculations.

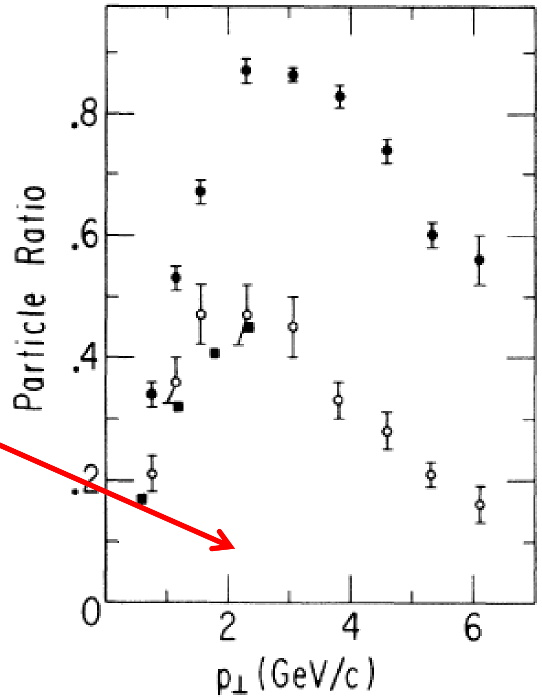


FIG. 20. Comparison of the cross-section ratio p/π^+ measured on tungsten at $\sqrt{s}=23.7$ GeV (closed circles), with that obtained by extrapolation to $A=1$ (open circles). Ratios obtained from the British-Scandinavian collabortion (Ref. 23) at $\sqrt{s}=23.4$ GeV are also plotted (closed squares).

V.S. Pantuev *Physics of Atomic Nuclei, 2009, Vol. 72, No. 12, pp. 1971–1981*

Modern Physics Letters A, Vol. 3, No. 9 (1988) 909–916

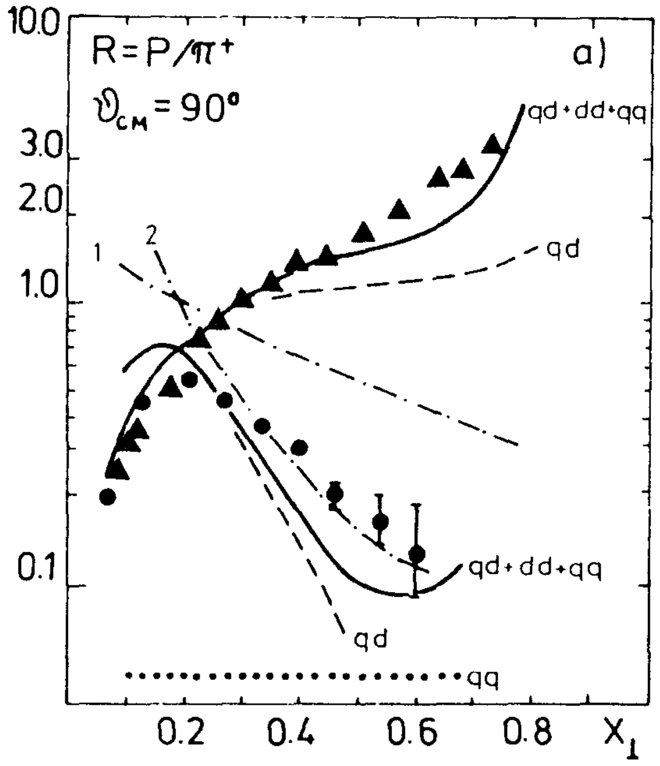
DIQUARKS AND DYNAMICS OF LARGE-$P_\perp$ BARYON PRODUCTION

V. T. KIM

Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, 101000 Moscow

Received 4 January 1988

In the framework of a diquark model of the nucleon, the strong scaling violation of the p/π^+-ratio in the pp-collisions from $\sqrt{s} = 11.5$ GeV (IHEP, Serpukhov) to $\sqrt{s} = 23.4$ GeV (FNAL) and to $\sqrt{s} = 62$ GeV (CERN ISR) is described. A fairly good description of the magnitude of cross sections for single protons and for symmetric-proton-pairs with large-$p_\perp$ is obtained. In the model with the dominating scalar (ud)-diquark, the yield relation $\Lambda^0/p \simeq K^+/\pi^+$ is predicted.



Diquarks

pp -> p(π)+X, pp -> pp+X

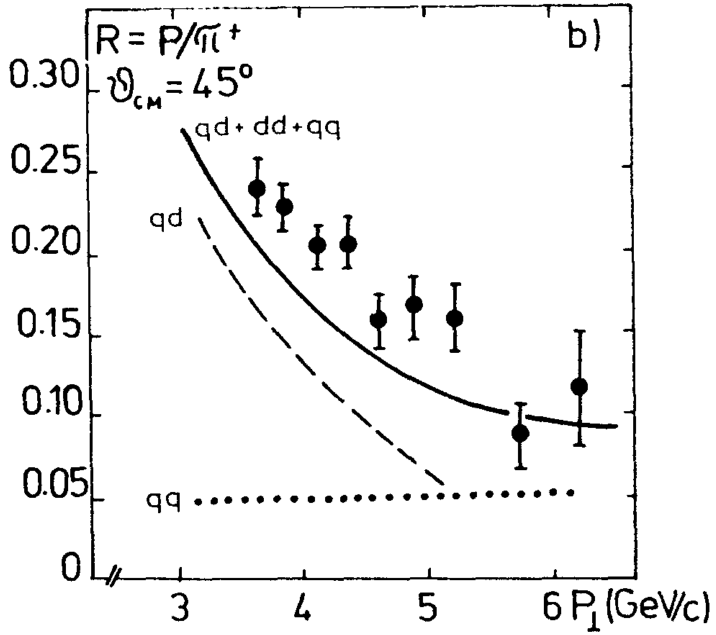


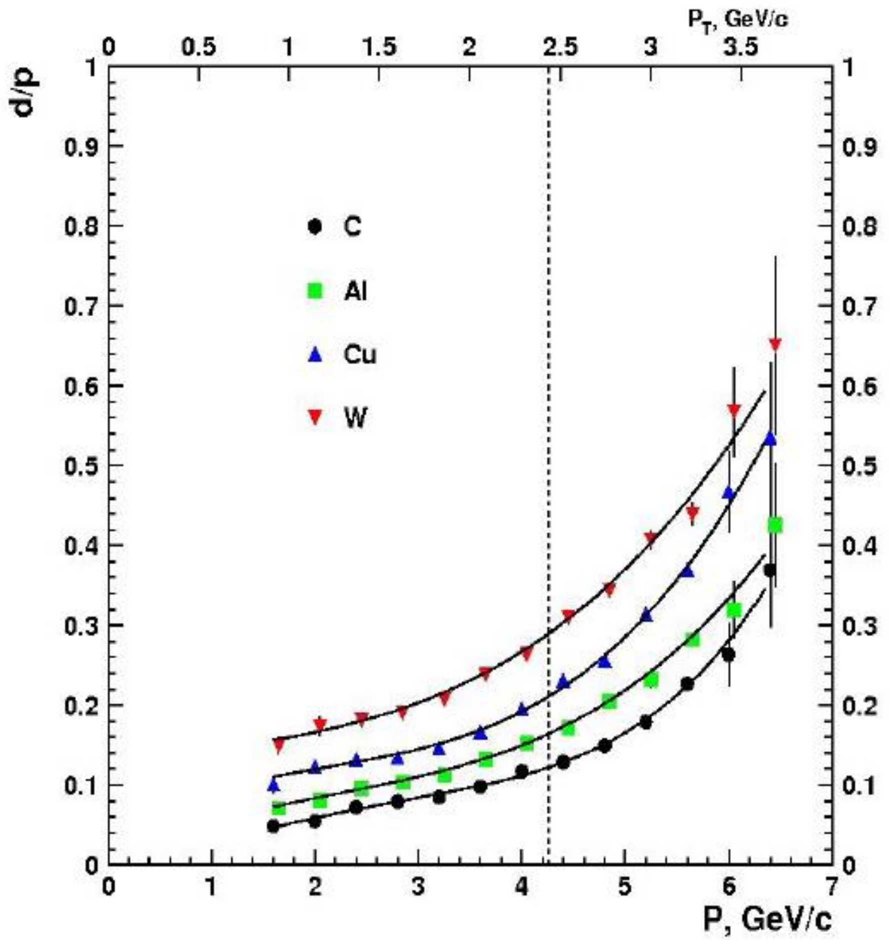
Fig. 1. $R = p/\pi^+$ is the particle yield ratio in the pp-collisions.
a) $\vartheta_{CM} = 90°$: • the FNAL data[1] at $\sqrt{s} = 23.4$ GeV ($E = 300$ GeV); ▲ the IHEP (Serpukhov) data[2] at $\sqrt{s} = 11.5$ GeV ($E = 70$ GeV).
b) $\vartheta_{CM} = 45°$: • the CERN ISR data[3] at $\sqrt{s} = 62$ GeV ($E \simeq 1900$ GeV).
The dotted curve shows the contribution of the qq-subprocess, the dashed one shows the contribution of the qd-subprocess. The total contribution of the qq-, qd- and dd-subprocesses is denoted by the solid lines. The dashed-dotted curves show the calculations with the diquark function $G_d^N(x) \sim (1-x)/x$ at 70 GeV (curve 1) and at 300 GeV (curve 2).

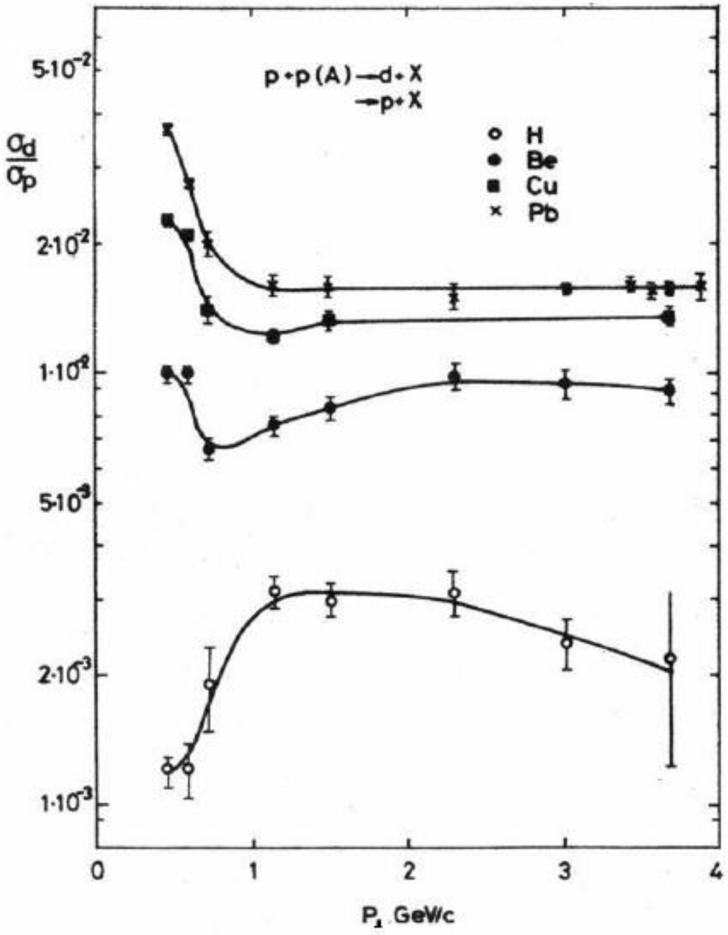
SPIN data

Ratio d/p

отношение выхода дейтронов к выходу протонов как функция импульса

ФОДС В.В.Абрамов и др., ЯФ 45(5) (1987), 845–851





объединенный
институт
ядерных
исследований
дубна

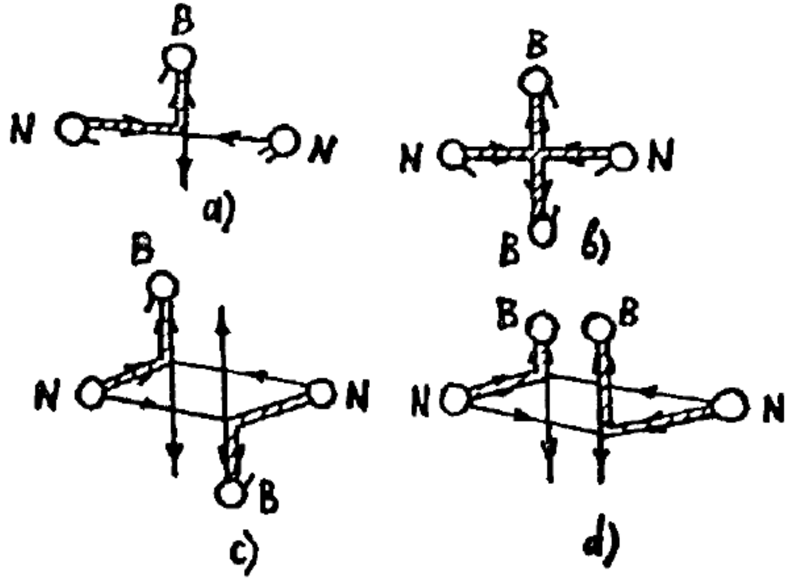
E2-87-74

A.V.Efremov, V.T.Kim

DIQUARKS ROLE
IN LARGE-$p_\perp$ DEUTERON
AND H-DIHYPERON PRODUCTION
IN HARD NUCLEON COLLISIONS

Submitted to "Physics Letters"

1987



F i g. 2. The subprocesses diagrams giving contributions to the $B = N$, Λ^0 -baryon production in hard NN -collision: a) the quark-diquark subprocess; b) the diquark-diquark subprocess; c),d) the double quark-diquark collisions.

The proposed mechanism of simultaneous double quark-diquark collision can describe main features of large-$p_\perp$ deuteron production in pp-collisions at $\sqrt{s} = 11.5$ GeV (IHEP, Serpukhov/2/). The predictions are made for the energy $\sqrt{s} = 23.4$ GeV.

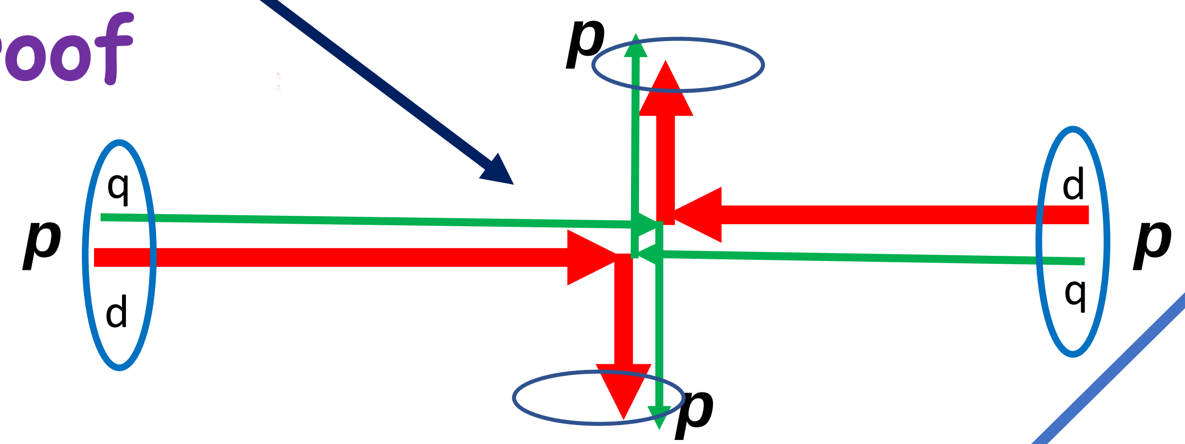
The possibility of the H-dihyperon production in pp-collisions in the framework of the double quark-diquark collision mechanism is noted.

Exotics states

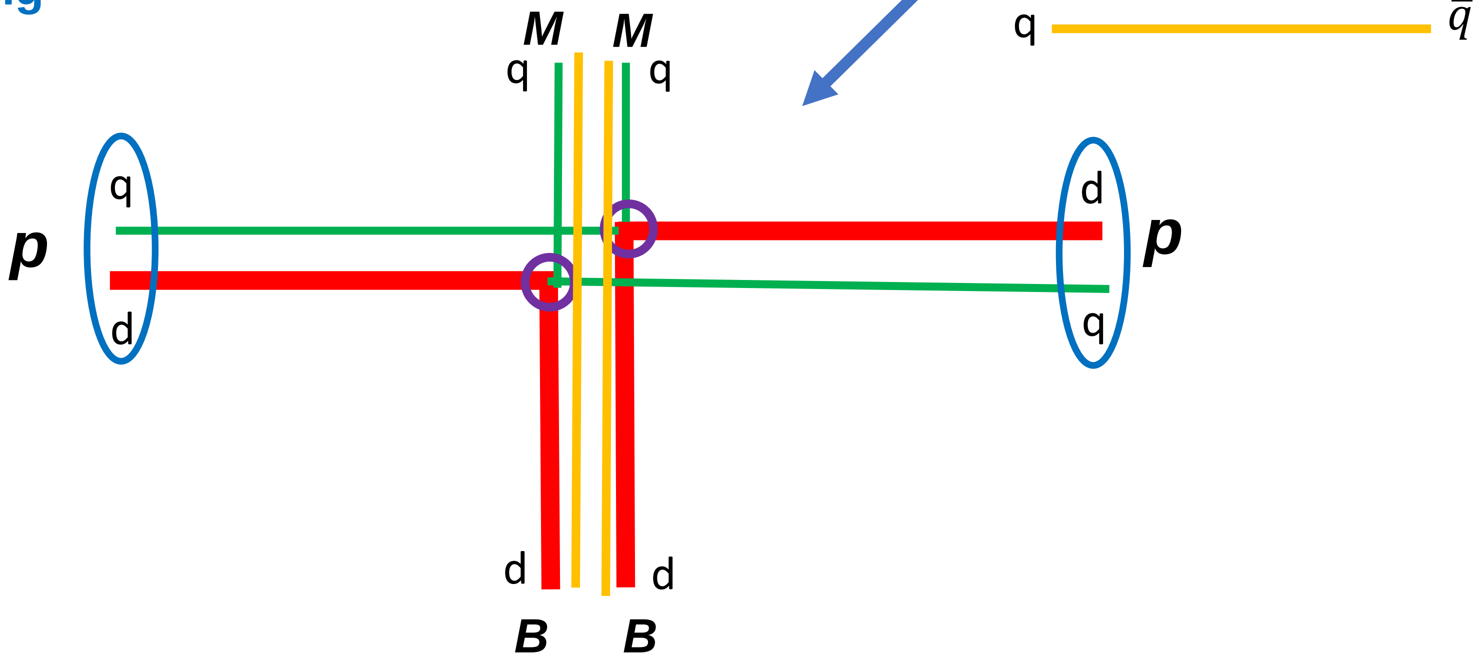
$H = \Lambda\Lambda$

pp - > pp , pp -> D+MM; H + K^+K^+

Diquark proof



Double *qd*-scatering



Где мы явно видим составляющие кварки?

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 ($\theta_{cm} > 40°$) reaction at large momentum transfers $Q = \sqrt{-t}$:

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

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

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 $t=(p_A-p_C)^2$,

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

PHYSICAL REVIEW D VOLUME 49, NUMBER 1 1 JANUARY 1994

Comparison of 20 exclusive reactions at large t

C. White,[4,*] R. Appel,[1,5,†] D. S. Barton,[1] G. Bunce,[1] A. S. Carroll,[1]
H. Courant,[4] G. Fang,[4,‡] S. Gushue,[1] K. J. Heller,[4] S. Heppelmann,[2]
K. Johns,[4,§] M. Kmit,[1,∥] D. I. Lowenstein,[1] X. Ma,[3] Y. I. Makdisi,[1]
M. L. Marshak,[4] J. J. Russell,[3]
and M. Shupe[4,§]

TABLE IV. Cross sections at 90 degrees and 5.9 GeV/c incident beam momentum. Reaction number refers to Fig. 27. The values represent interpolations where the range spans 90°.

Number	Reaction	Cross section [nb/(GeV/c)^2]
1	$\pi^+ p \to p\pi^+$	132 ± 10
2	$\pi^- p \to p\pi^-$	73 ± 5
3	$K^+ p \to pK^+$	219 ± 30
4	$K^- p \to pK^-$	18 ± 6
5	$\pi^+ p \to p\rho^+$	214 ± 30
6	$\pi^- p \to p\rho^-$	99 ± 13
7	$K^+ p \to pK^{*+}$	$291 + 47 - 130$
8	$K^- p \to pK^{*-}$	$15 + 10 - 13$
9	$K^- p \to \pi^- \Sigma^+$	50 ± 21
10	$K^- p \to \pi^+ \Sigma^-$	4 ± 3
11	$K^- p \to \Lambda\pi^0$	< 80
12	$\pi^- p \to \Lambda K^0$	< 5
13	$\pi^+ p \to \pi^+ \Delta^+$	45 ± 10
14	$\pi^- p \to \pi^- \Delta^+$	20 ± 11
15	$\pi^- p \to \pi^+ \Delta^-$	24 ± 5
16	$K^+ p \to K^+ \Delta^+$	< 230
17	$pp \to pp$	3300 ± 40
18	$\bar{p}p \to p\bar{p}$	75 ± 8
19	$\bar{p}p \to \pi^+\pi^-$	7 ± 3
20	$\bar{p}p \to K^+K^-$	2 ± 2

Shimanskiy S.S.

TABLE V. The scaling between E755 and E838 has been measured for eight meson-baryon and 2 baryon-baryon interactions at $\theta_{c.m.} = 90°$. The nominal beam momentum was 5.9 GeV/c and 9.9 GeV/c for E838 and E755, respectively. There is also an overall systematic error of $\Delta n_{syst} = \pm 0.3$ from systematic errors of $\pm 13\%$ for E838 and $\pm 9\%$ for E755.

No.	Interaction	Cross section E838	Cross section E755	n-2 $(\frac{d\sigma}{dt} \sim 1/s^{n-2})$
1	$\pi^+ p \to p\pi^+$	132 ± 10	4.6 ± 0.3	6.7 ± 0.2
2	$\pi^- p \to p\pi^-$	73 ± 5	1.7 ± 0.2	7.5 ± 0.3
3	$K^+ p \to pK^+$	219 ± 30	3.4 ± 1.4	$8.3^{+0.6}_{-1.0}$
4	$K^- p \to pK^-$	18 ± 6	0.9 ± 0.9	≥ 3.9
5	$\pi^+ p \to p\rho^+$	214 ± 30	3.4 ± 0.7	8.3 ± 0.5
6	$\pi^- p \to p\rho^-$	99 ± 13	1.3 ± 0.6	8.7 ± 1.0
13	$\pi^+ p \to \pi^+ \Delta^+$	45 ± 10	2.0 ± 0.6	6.2 ± 0.8
15	$\pi^- p \to \pi^+ \Delta^-$	24 ± 5	≤ 0.12	≥ 10.1
17	$pp \to pp$	3300 ± 40	48 ± 5	9.1 ± 0.2
18	$\bar{p}p \to p\bar{p}$	75 ± 8	≤ 2.1	≥ 7.5

Shimanskiy S.S.

Soft Perturbative QCD* NORDITA-1999/52 HE

hep-ph/9908501

Paul Hoyer August 30, 1999

The way the differential large angle $2 \to 2$ particle scattering cross sections should scale with energy (momentum transfer) was envisaged by the so-called "quark counting rules" [26].

$$\frac{d\sigma}{dt} = \frac{f(\Theta)}{s^{K-2}}; \qquad \frac{t}{s} = \text{const},$$

with K the number of *elementary fields* (quarks, photons, leptons, etc.) among / inside the initial and final particles.

For example, in the case of the deuteron break-up by a photon, $\gamma + D \to p + n$, we have $K = 1 + 6 + 6 = 13$ (a photon and 6 quarks inside the initial deuteron and another 6 in the final proton and neutron). So, the differential cross section is expected to fall with s, *asymptotically*, as $s^{-11} = E_{\rm c.m.}^{-22}$.

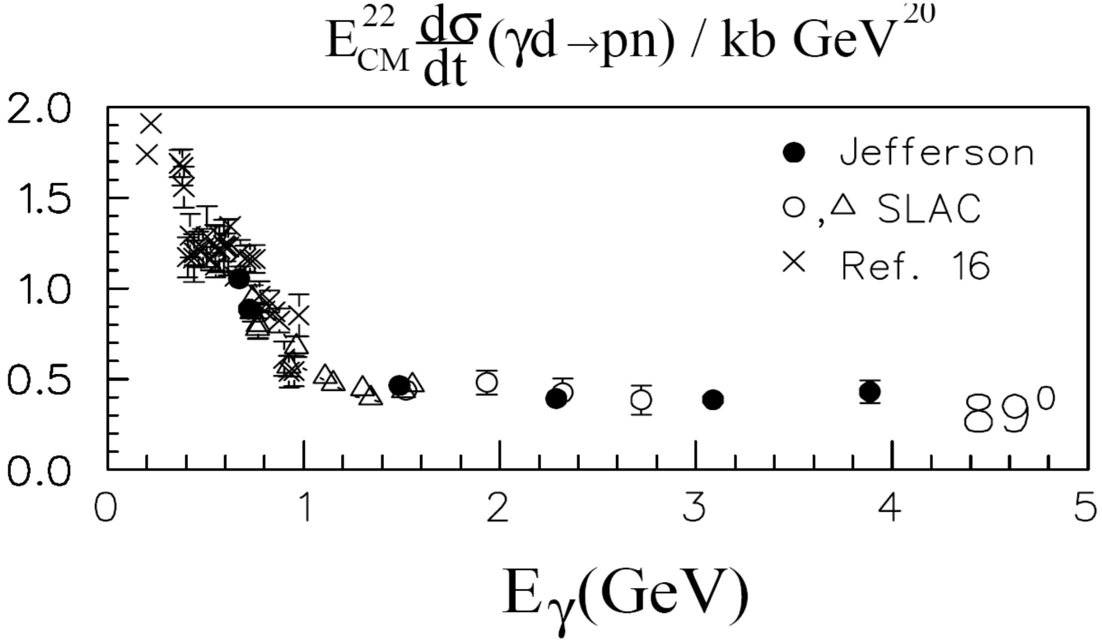
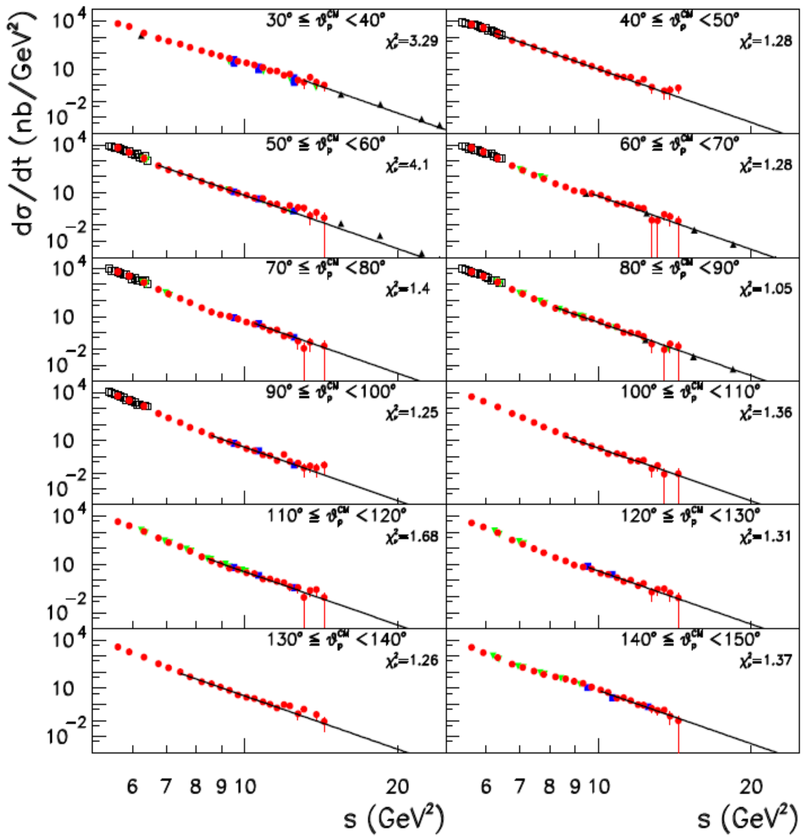


FIG. 2. The $\gamma d \to pn$ cross section at 89° multiplied by E_{CM}^{22} as a function of the photon beam energy [3].

Light-Front QCD*

Stanley J. Brodsky

SLAC–PUB–10871
November 2004



$$s^{11}\frac{d\sigma}{dt}(\gamma d \to pn) \sim$$

constant at fixed CM angle

Figure 8: Fits of the cross sections $d\sigma/dt$ to s^{-11} for $P_T \geq P_T^{th}$ and proton angles between 30° and 150° (solid lines). Data are from CLAS (full/red circles), Mainz(open/black squares), SLAC (full-down/green triangles), JLab Hall A (full/blue squares) and Hall C (full-up/black triangles). Also shown in each panel is the χ^2_ν value of the fit. From Ref. [160].

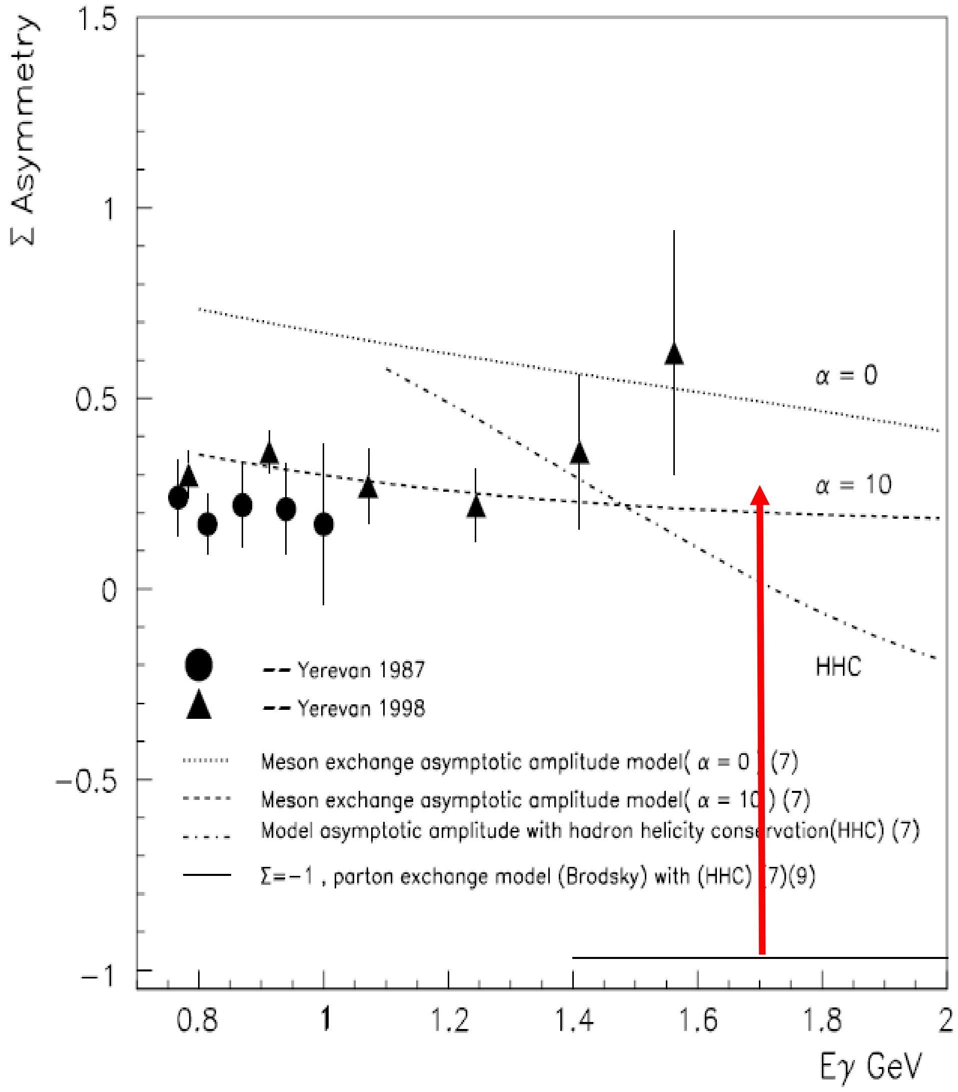


Fig. 8. The energy dependence of the cross-section asymmetry Σ for $\theta_p = 90°$ in the cms.

Eur. Phys. J. A **8**, 423–428 (2000)

THE EUROPEAN PHYSICAL JOURNAL A

Measurement of the cross-section asymmetry of deuteron photodisintegration process by linearly polarized photons in the energy range $E_\gamma = 0.8$–1.6 GeV

F. Adamian[1], A. Aganiants[1], Yu. Borzunov[2], S. Chumakov[2], N. Demekhina[1], G. Frangulian[1], L. Golovanov[2], V. Grabski[1,a], A. Hairapetian[1], H. Hakobyan[1], I. Keropian[1], I. Lebedev[1], Zh. Manukian[1], N. Moroz[2], G. Movsesian[1], E. Muradian[1], A. Oganesian[1], R. Oganezov[1], Yu. Panebratsev[2], M. Rekalo[3], S. Shimanski[2], A. Sirunian[1], H. Torosian[1], A. Tsvenev[2], H. Vartapetian[1], and V. Volchinski[1]

[1] Yerevan Physics Institute, Armenia
[2] Joint Institute for Nuclear Research, Dubna, Russia
[3] Kharkov Institute of Physics and Technology, Kharkov, Ukraine

$$\Sigma = (N_n \rightarrow - N_n \uparrow)/(\bar{P}_\gamma \uparrow N_n \rightarrow + \bar{P}_\gamma \rightarrow N_n \uparrow)$$

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 $pd \to pd$

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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 $\theta_{cm} = 125-135^\circ$ follows the scaling regime $\sim s^{-16}$ at beam energies 0.5–5 GeV. These data are parameterized here using the Reggeon exchange.

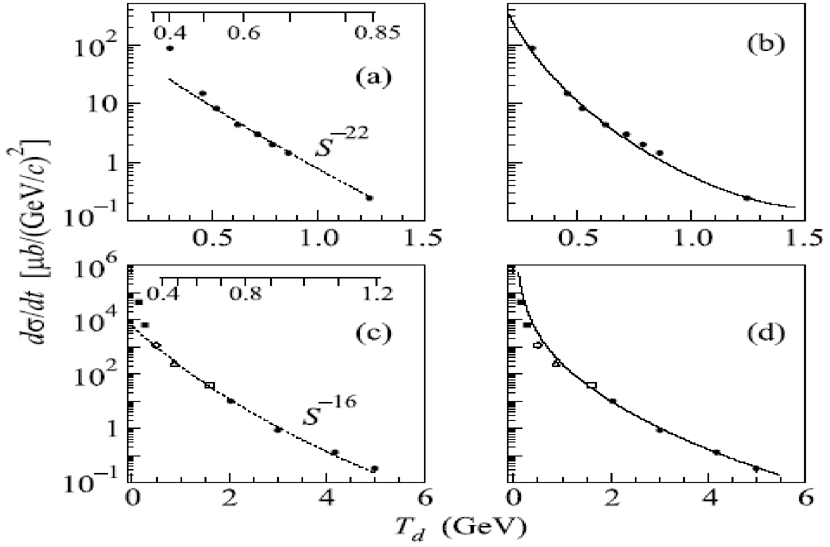


Fig.2. The differential cross section of the $dd \to n^3$He and $dd \to p^3$H reactions at $\theta_{cm} = 60^o$ (a), (b) and $dp \to dp$ at $\theta_{cm} = 127^o$ (c), (d) versus the deuteron beam kinetic energy. Experimental data in (a), (b) are taken from [20]. In (c), (d), the experimental data (black 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) – $C_1 = 1.9\,\mathrm{GeV}^2$, $R_1^2 = 0.2\,\mathrm{GeV}^{-2}$, $C_2 = 3.5$, $R_2^2 = -0.1\,\mathrm{GeV}^{-2}$; (d) – $C_1 = 7.2\,\mathrm{GeV}^2$, $R_1^2 = 0.5\,\mathrm{GeV}^{-2}$, $C_2 = 1.8$, $R_2^2 = -0.1\,\mathrm{GeV}^{-2}$. The upper scales in (a) and (c) show the relative momentum q_{pn} (GeV/c) in the deuteron for the ONE mechanism

F. Lehar, Current experiments using polarized beams of the JINR LHE accelerator complex,
Phys.Part.Nucl. 36 (2005) 501-528

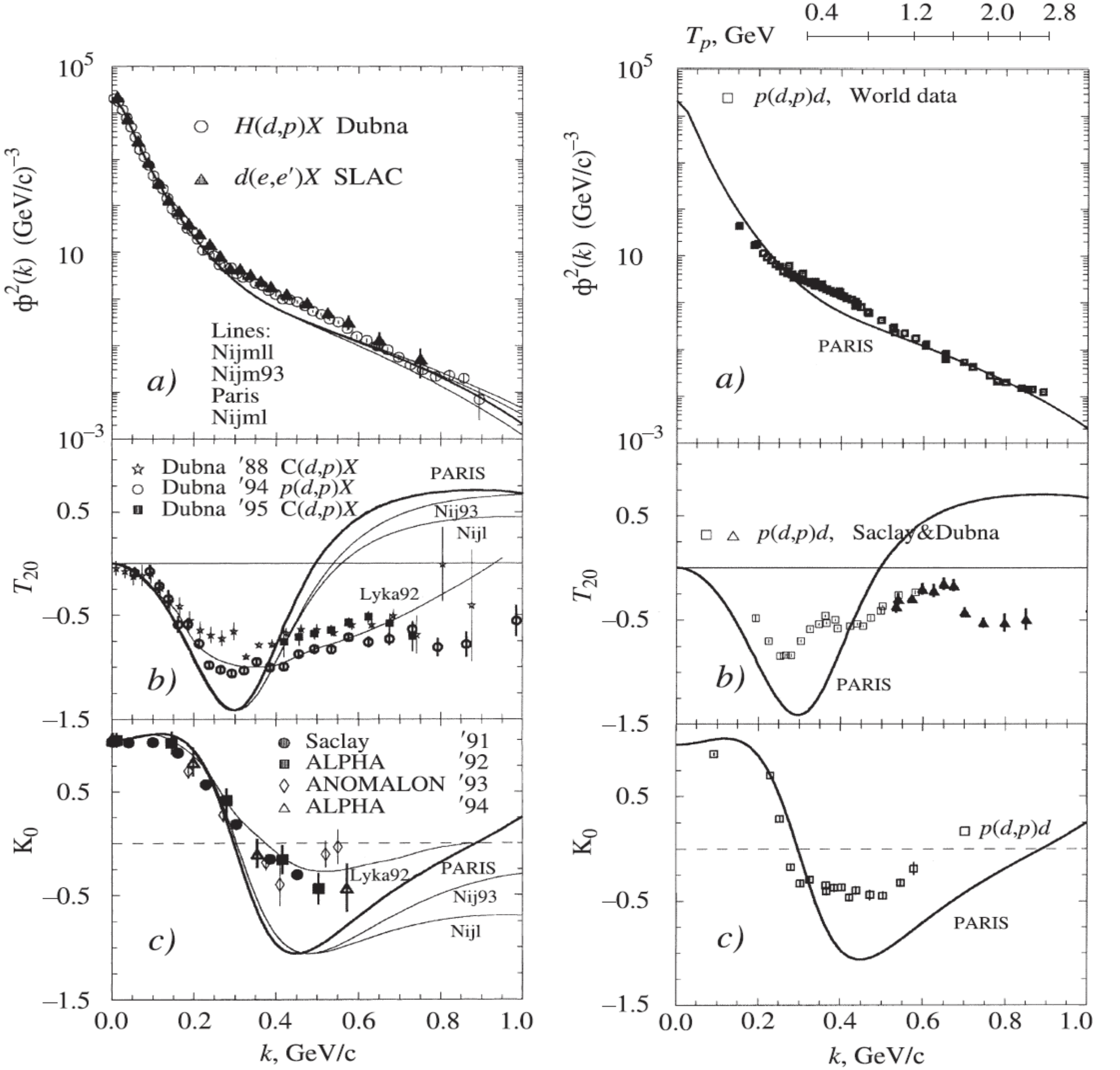


Рис. 5. Сводка данных экспериментов по фрагментации (слева) и упругому рассеянию «назад» (справа) поляризованных и неполяризованных дейтронов

Color Transparency

arXiv:1208.3668v1 [nucl-th] 17 Aug 2012

Gerald A. Miller

Physics Department, Univ. of Washington, Seattle, Wa. 98195-1560, USA

Abstract. Color transparency is the vanishing of nuclear initial or final state interactions involving specific reactions. The reasons for believing that color transparency might be a natural consequence of QCD are reviewed. The main impetus for this talk is recent experimental progress, and this is reviewed briefly.

The basic idea is that some times a hadron is in a color-neutral point-like configuration PLC. If such undergoes a coherent reaction, in which one sums gluon emission amplitudes to calculate the scattering amplitude, the PLC does not interact with the surrounding media. A PLC is not absorbed by the nucleus. The nucleus casts no shadow. This is a kind of quantum mechanical invisibility.

Progress in Particle and Nuclear Physics 69 (2013) 1–27

Review

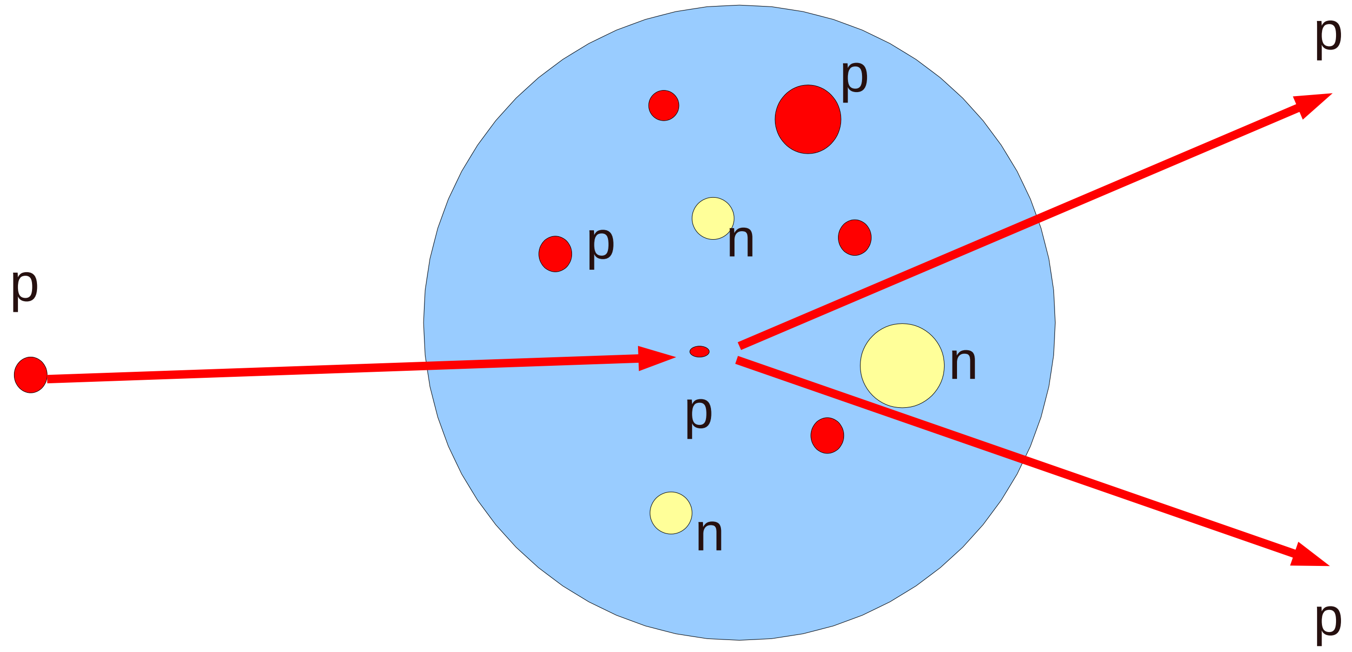
Color transparency: Past, present and future

D. Dutta [a,*], K. Hafidi [b], M. Strikman [c]

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

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

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



Shimanskiy S.S.

VOLUME 87, NUMBER 21 PHYSICAL REVIEW LETTERS 19 NOVEMBER 2001

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

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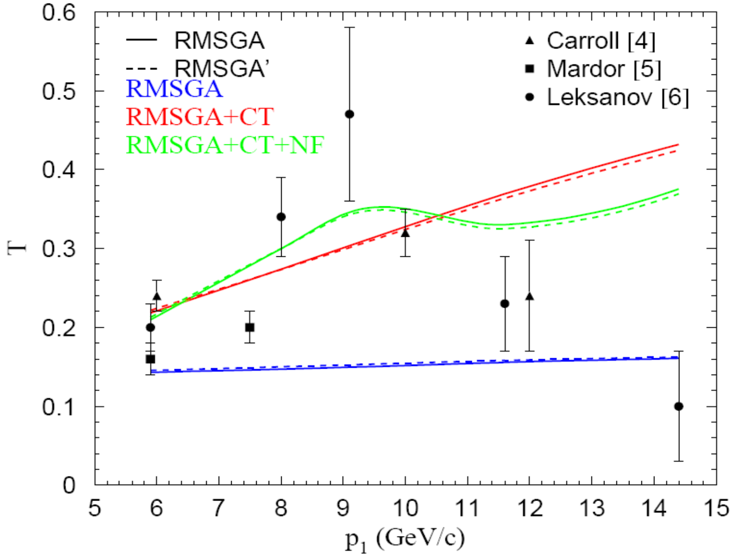
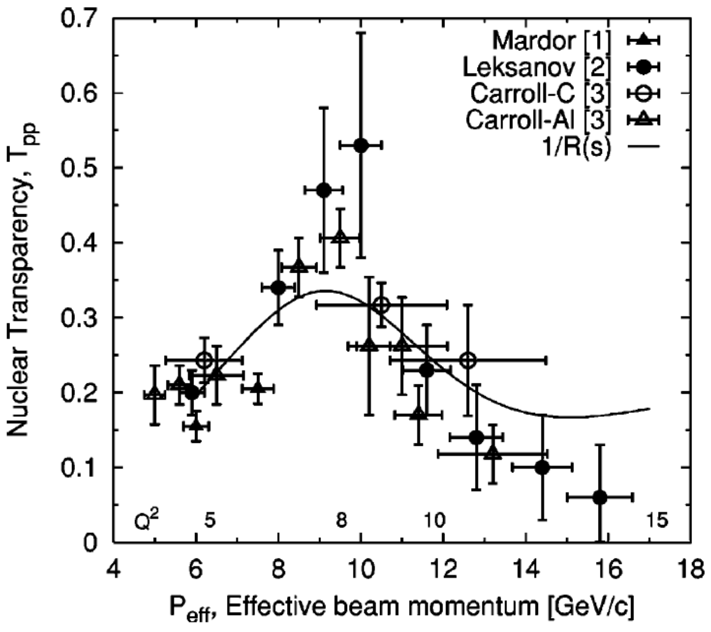
B.Van Overmeire, J.Ryckebusch, nucl-th/0608040



J. Aclander et al., Phys.Rev. C 70, 015208 (2004)



J. Aclander et al., Phys.Rev. C 70, 015208 (2004)

COLOR TRANSPARENCY FUTURE

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 ~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 $90^{\circ}_{\text{c.m.}}$. For instance, the pp differential cross section at $90^{\circ}_{\text{c.m.}}$ 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].

FODS (IHEP, Protvino)!

ПОЛЯРИЗАЦИЯ

E. Leader, Spin in Particle Physics
© Cambridge University Press, 2001

p.Xiv

“Spin plays a dramatic Jekyll and Hyde role in the theatre of elementary particle physics, acting sometimes as the harbinger of the demise of a current theory, sometimes as a powerful tool in the confirmation and verification of such a theory”.

“Спин играет драматическую роль Джекилл и Хайда в театре физики элементарных частиц, иногда выступая в качестве предвестника упадка существующей теории, а иногда, выступая в качестве мощного орудия проверки и подтверждения такой теории”.

Alan Krisch
DSPIN'09, Dubna

For the past 30 years QCD-based calculations have continued to disagree with the ZGS 2-spin & AGS 1-spin elastic data and the ZGS, AGS, Fermilab & RHIC inclusive data.

* These large spin effects do not go to zero at high-energy or high-$P_{\perp}$ as was predicted.
* No QCD-based model can explain all the large spin effects.

BASIC PRINCIPLE OF SCIENCE:
If a theory does not agree with reproducible experimental data, then the theory must be modified.

These precise spin experiments provide experimental guidance for the required modification of the theory of Strong Interactions.

Elastic $d\sigma/dt$, A_{nn} and A_n experiments at higher energy and $P_{\perp}$ could provide more guidance, just as the RHIC inclusive A_n experiments confirmed the similar Fermilab experiments. (E-704 Yokosawa et al.).

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

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The energy dependence of the spin-parallel and spin-antiparallel cross sections for $p_{\uparrow}+p_{\uparrow}\to p+p$ at $90°_{c.m.}$ was measured for beam momenta between 6 and 12.75 GeV/c. The ratio $(d\sigma/dt)_{parallel}:(d\sigma/dt)_{antiparallel}$ 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 $P_{\perp}^2$.

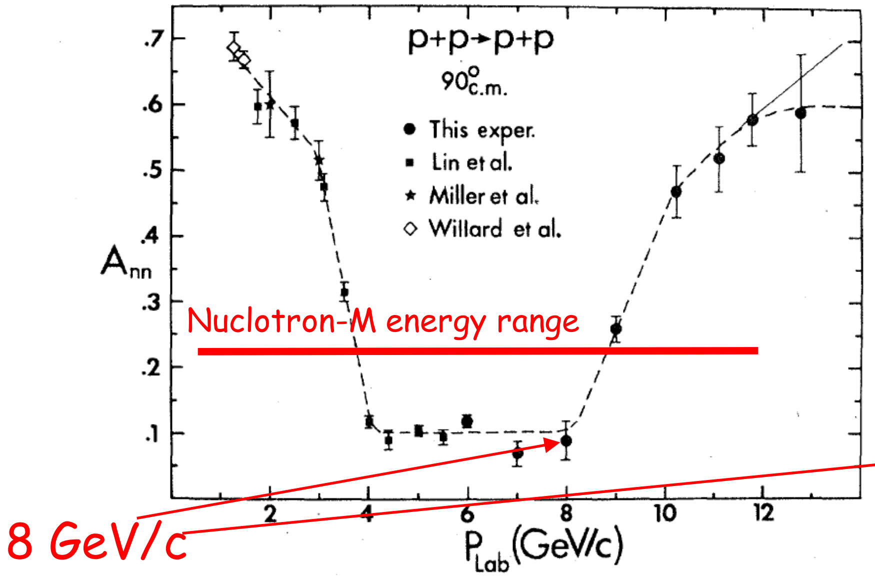


FIG. 2. Plot of the spin-spin correlation parameter A_{nn} for $p+p\to p+p$ at $90°_{c.m.}$ as a function of incident beam momentum. The dashed and solid lines are hand-drawn possible fits.

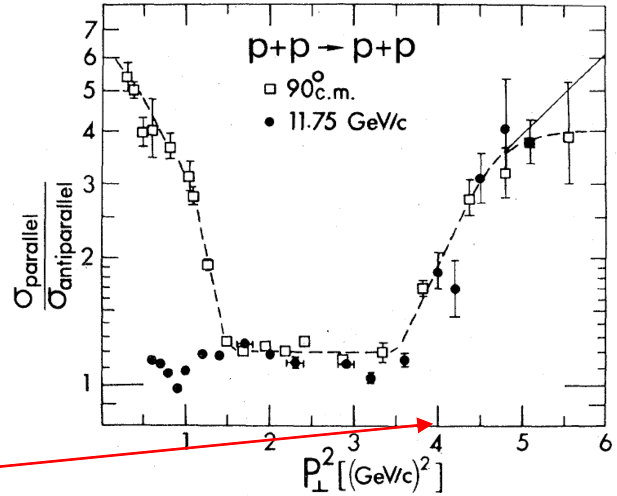


FIG. 3. Plot of the ratio of the spin-parallel to spin-antiparallel differential cross sections, as a function of $P_{\perp}^2$, for p-p elastic scattering. The squares are the fixed-angle data at $90°_{c.m.}$, with the incident energy varied. The circles are data (Refs. 5, 11) with the momentum held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

Shimanskiy S.S.

AGS 1985-1990 A_n

PERTURBATIVE QCD $\Rightarrow$

$A_n = 0$ at HIGH $P_\perp^2$ and HIGH ENERGY

$A_n \neq 0 \Rightarrow$

PROBLEM with PQCD?

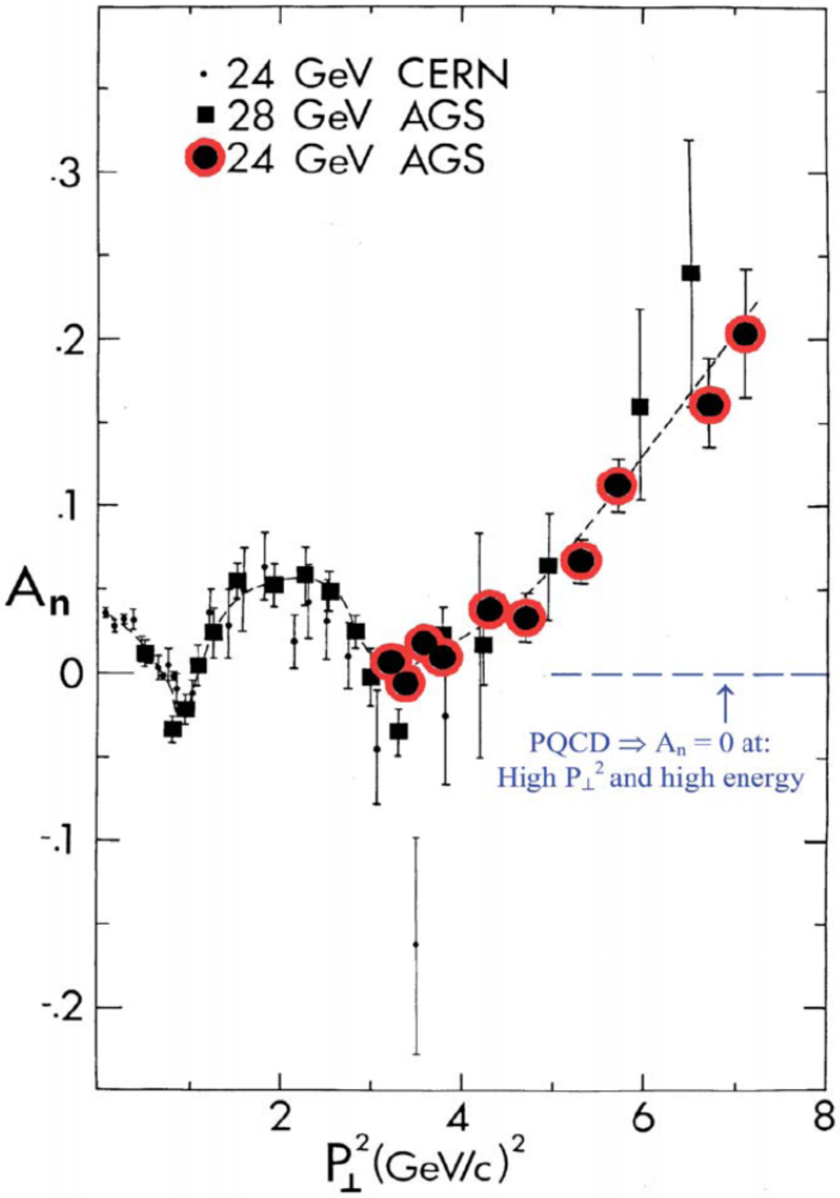
NO MODEL can EXPLAIN ALL

HIGH-$P_\perp^2$ SPIN EFFECTS (A_n & A_{nn})

GOAL

MEASURE A_n (and A_{nn})

up to $P_\perp^2$ = 12 (GeV/c)



INCLUSIVE PION PRODUCTION

200 GeV Polarized Proton Beam

from Polarized Hyperon Decay

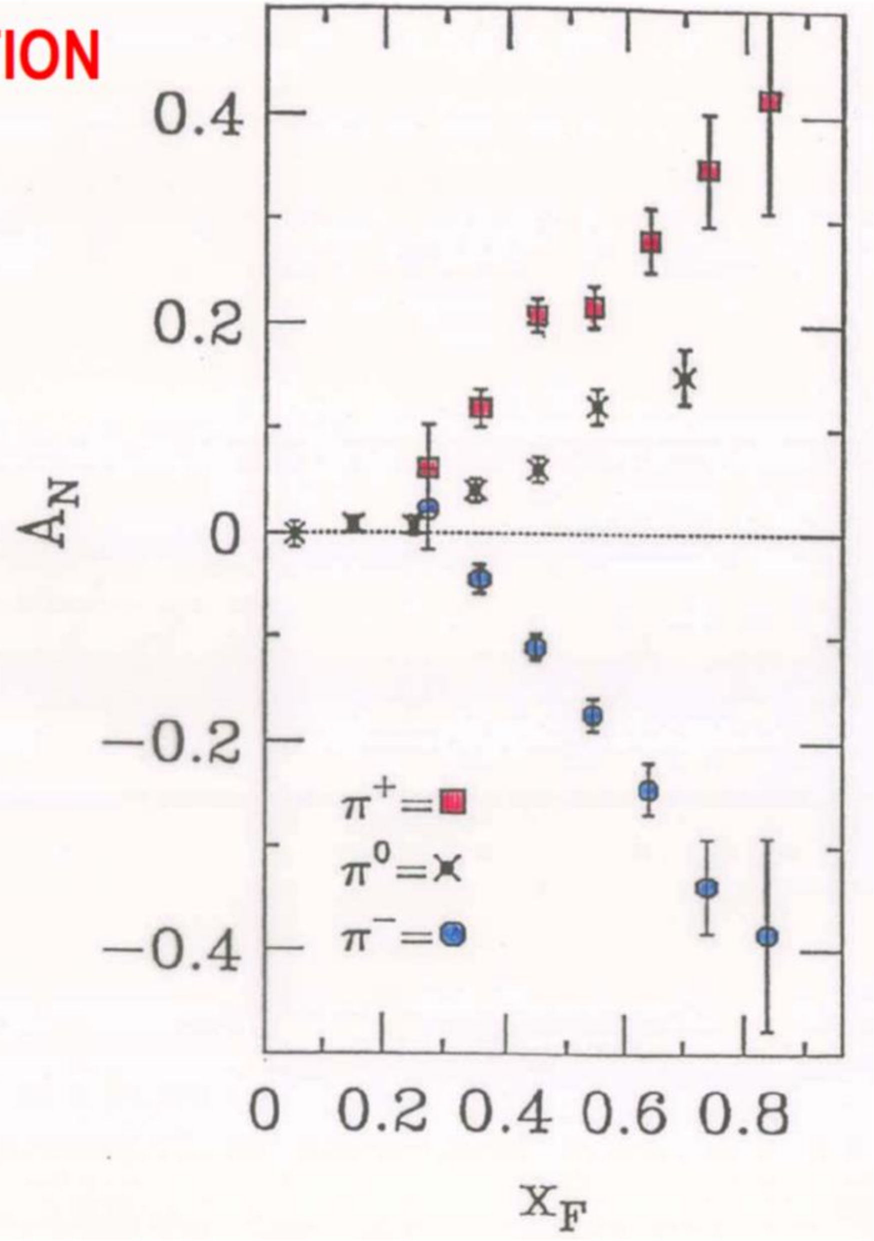
1990s Fermilab E-704

Yokosawa *et al.*

Phys Lett B264, 462 (1991)

A_n ~ 40%

QCD said A_n ~ 0



INCLUSIVE HYPERON POLARIZATION

Devlin, Pondrum, Bunce, Heller *et al.* 1976-80

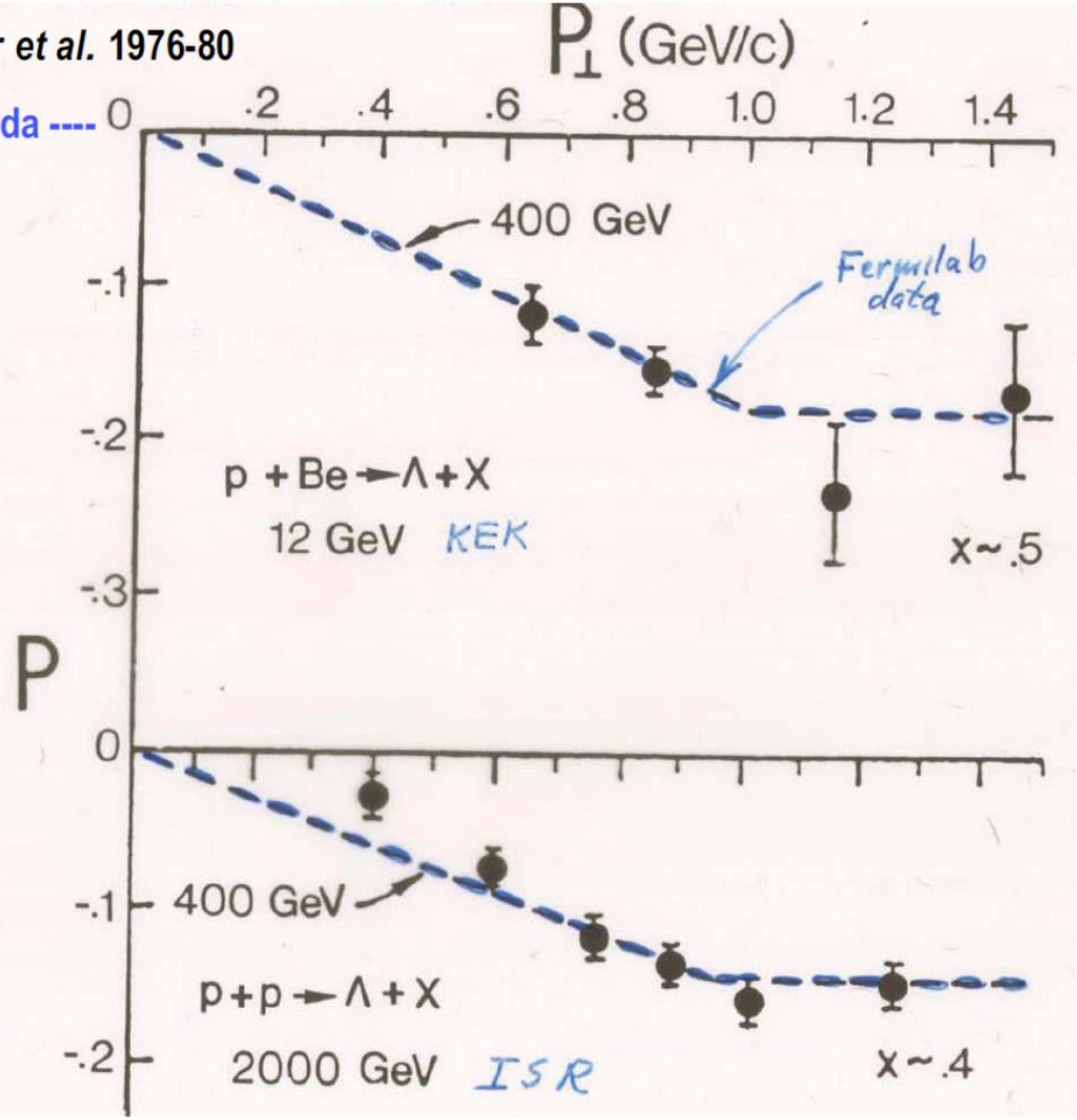
Fermilab 400 GeV p+p -> Lambda ----

Plot by Heller ~1980

with KEK & ISR data

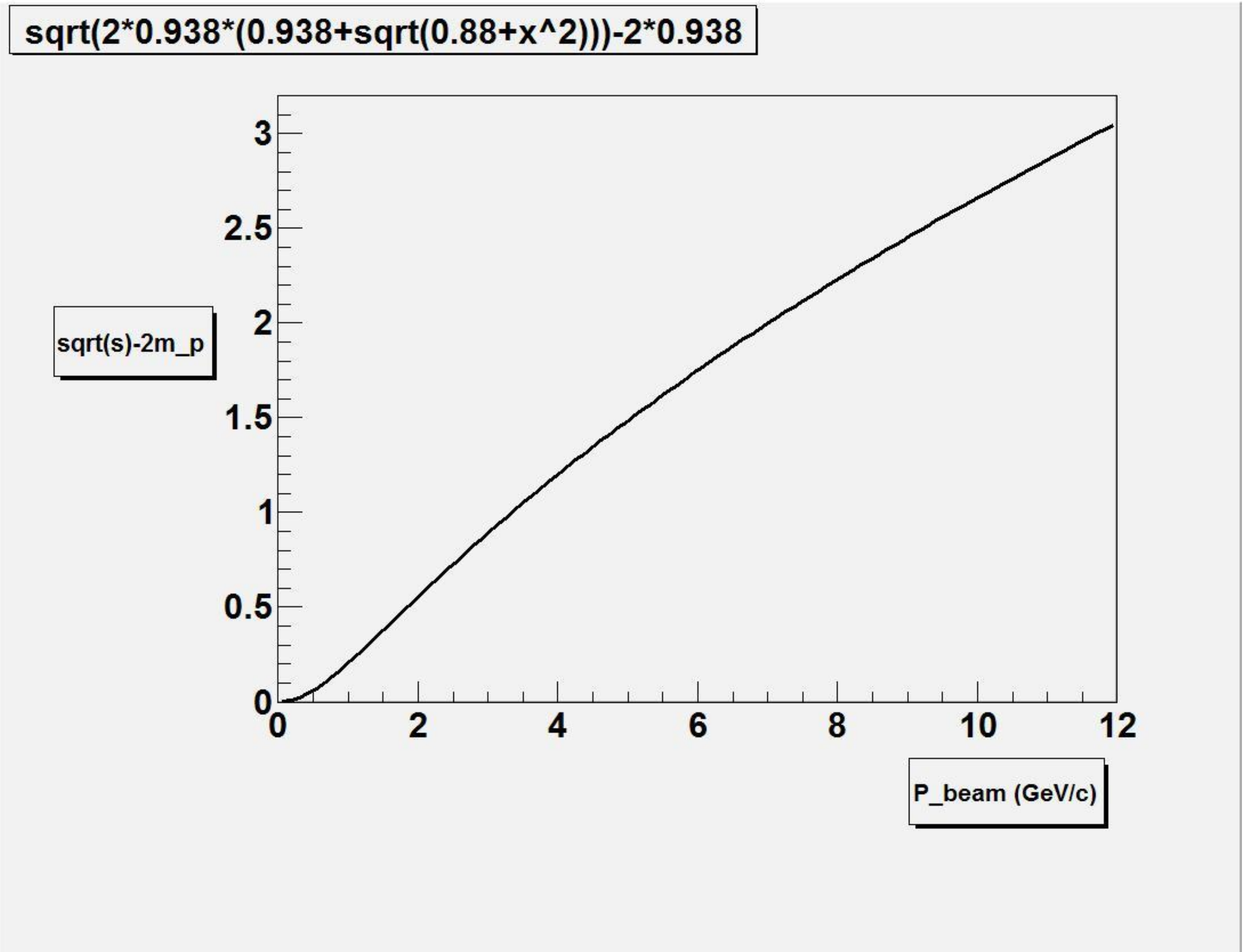
P ~ 15-20 %

QCD says P ~ 0



КАКИЕ ПРОБЛЕМЫ МЫ МОЖЕМ РЕШИТЬ НА КОМПЛЕКСЕ НИКА И … (?)

Nuclotron energy range



HIGH p_T ISSUES at SPD and …

NICA SPD

NN – interactions mainly

1. Flavor universality (pp- and nn-interactions) and polarization unique possibility for SPD.
2. Diquark. Proof of the existence and to define the properties.
3. Exotic states H(ΛΛ), tetra and pentaquarks, ….
4. Nature of the huge spin effects (spatially in exclusive reactions).
5. FSI (with s,c-quarks participation).
6. ΛN - hypernuclei ?
7. …

NA- and AA – interactions

1. Nature of CsDBM and CT (deep inelastic fusion).
2. Subthreshold J/Ψ production (polarization).
3. The Deuteron spin structure at small distance.
4. np(nn) dilepton anomaly.
5. …

NN Elastic scattering with polarized deuteron beams :

$$p\uparrow + p\uparrow \rightarrow p\uparrow + p\uparrow$$ for calibration

$$p\uparrow + n\uparrow \rightarrow p\uparrow + n\uparrow$$

$$n\uparrow + n\uparrow \rightarrow n\uparrow + n\uparrow$$

New data!

By the way we will have the counting rules verification!

pd, nd and dd – too!

Exclusive NN study at $x_T \sim 1$ for $\sqrt{s_{NN}} < 6$ GeV (correlation for higher energies)

$$N\uparrow + N\uparrow \to BB + MM$$

B (p,n,Λ, Δ...), M (π, K , ...)

Mechanisms of hyperons polarization

$$N\uparrow N\uparrow \to NN$$

$$N\uparrow N\uparrow \to BB + \pi\pi(KK)$$

$$N\uparrow N\uparrow \to \Delta\Delta$$

Detail vertexes studies and spin structure of the interaction vertexes:

$$q + (q) - (quark - quark)$$

$$q + (qq) - (quark - diquark)$$

$$(qq) + (qq) - (diquark - diquark)$$

How can we get evidence for the existence of diquarks?

Physics of Atomic Nuclei, Vol. 85, No. 2, 2022

arXiv:2109.12025v1 [hep-ph] 24 Sep 2021

Qualitative analysis of proton inelastic scattering for diquark searching

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Abstract

In this paper we discuss exclusive reactions which analysis can be used to receive direct indication of diquark existence. We make estimations of diquark scattering process measurement in inelastic proton-proton collisions. It was shown that putting special restrictions over kinematics and particles in final state of process it will be possible to enhance potential diquark contribution to scattering up to 10^4.

We put qualitative characteristics of process with diquark and ways to distinguish it from quark scattering in model-independent way.

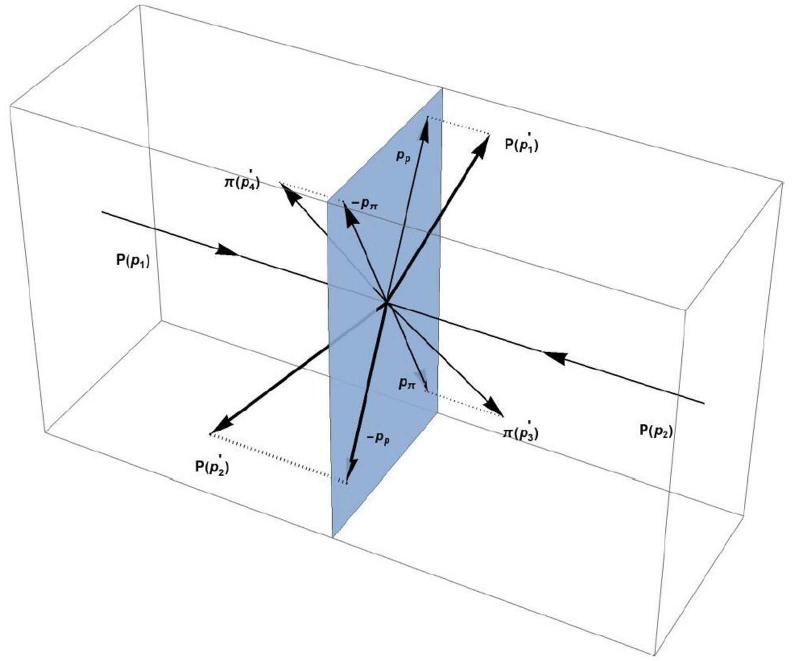


Figure 4: Kinematics of particles in pp collision in the case of diquark-diquark scattering.

High p_T exclusive reactions -> MPI

$$\frac{d\sigma(pp \to pp\pi^0\pi^0)}{d\sigma(pp \to pp\pi^+\pi^-)} \approx \frac{12}{7} \approx 1.7$$ With uu and ud diquarks

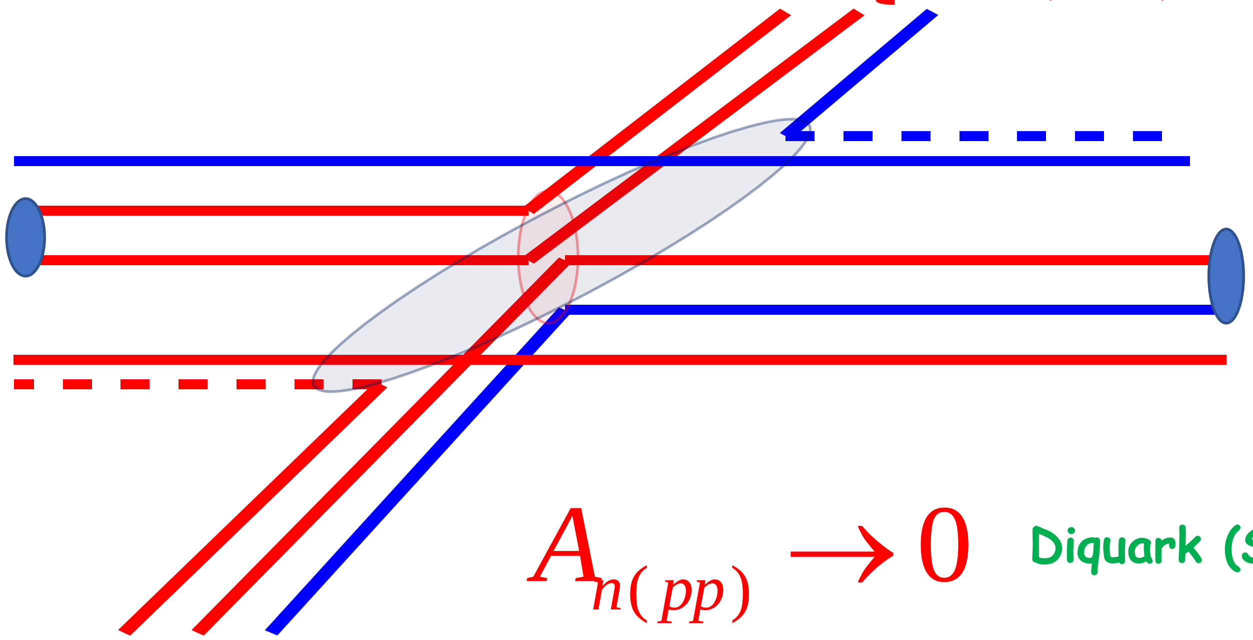
$$p\uparrow + p\uparrow \to B + B + M\overline{M}$$

$$p\uparrow + p\uparrow \to p + p + \pi^0\pi^0(\pi^+\pi^-)$$

$$R = \frac{N(\pi^+\pi^-)}{N(\pi^0\pi^0)} = \frac{2}{7}$$ Without diquark

$$R = \frac{N(\pi^+\pi^-)}{N(\pi^0\pi^0)} \to 0$$ Diquark ud only

diquark

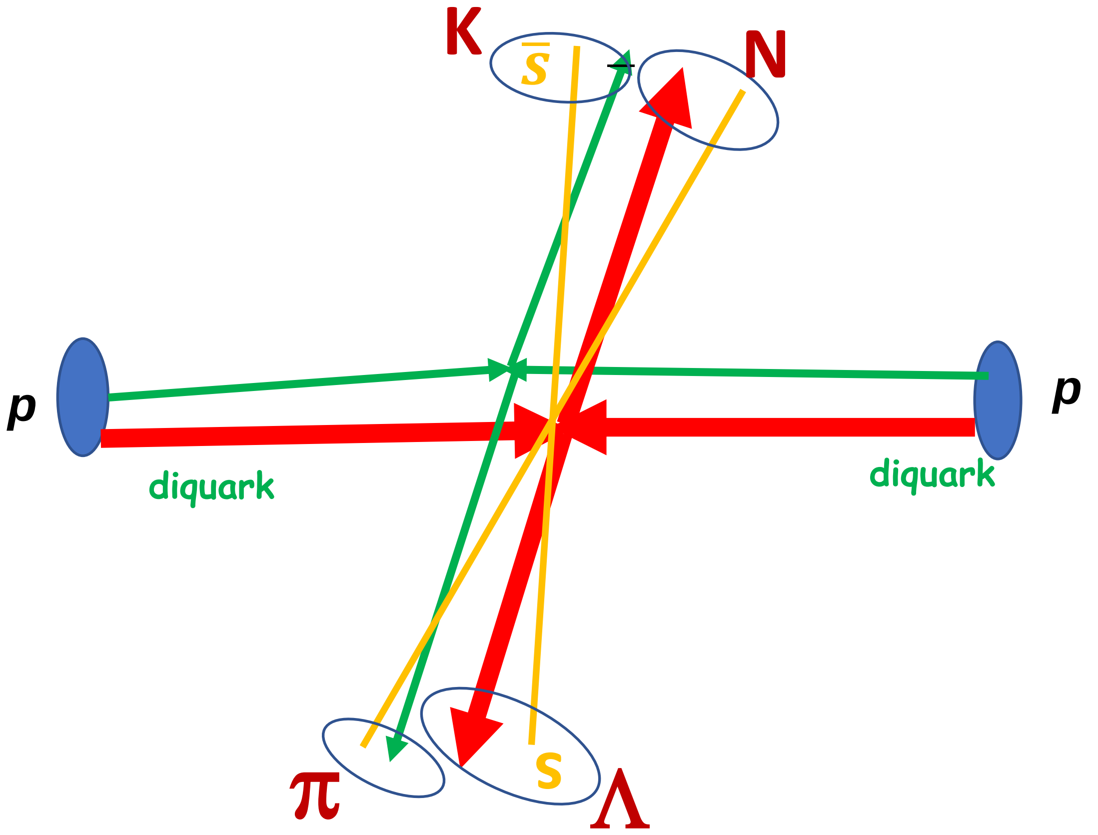


diquark

$$A_{n(pp)} \to 0$$ Diquark (S=0)

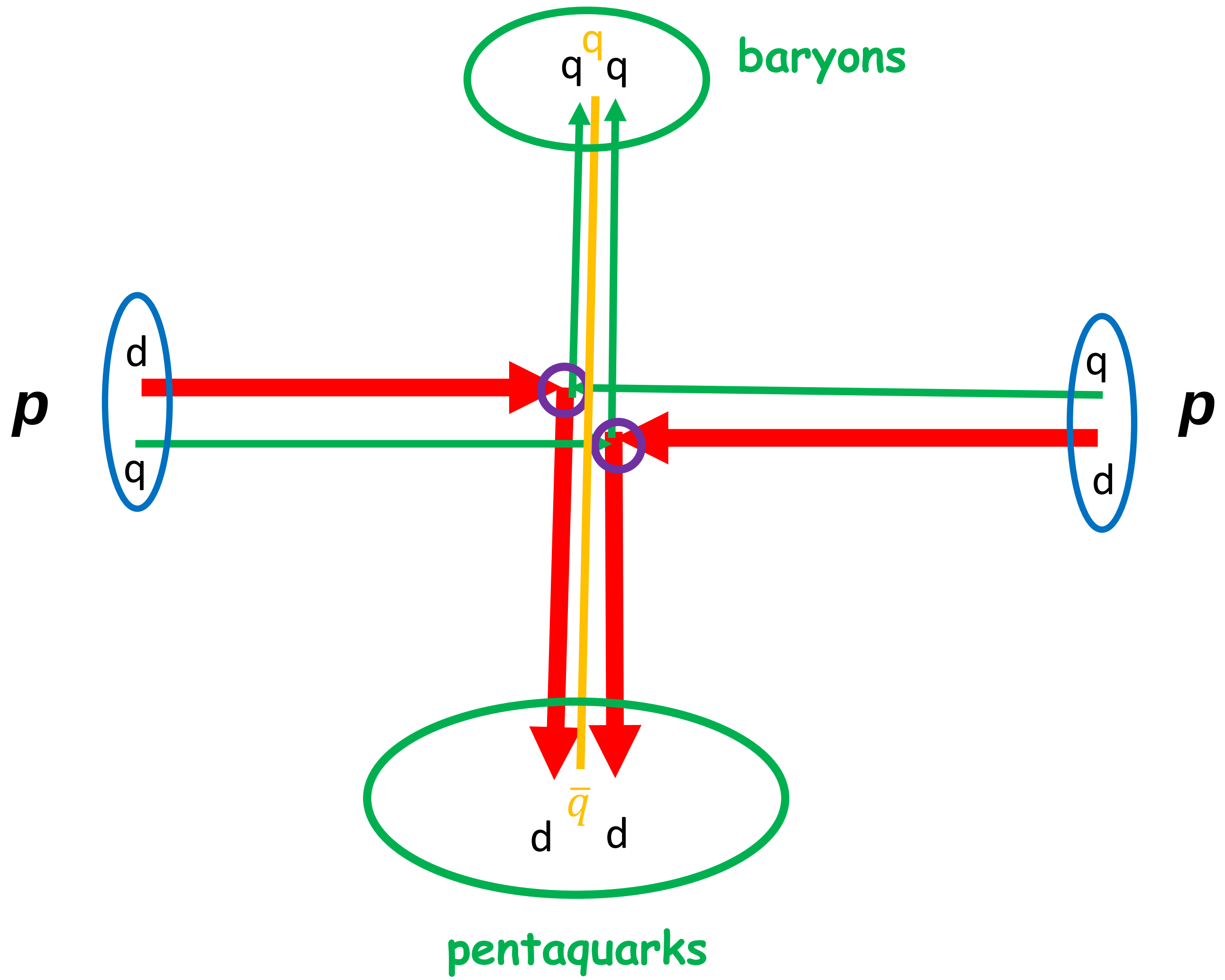
High p_T exclusive reactions -> MPI

$p + p \rightarrow \Lambda\pi + KN$



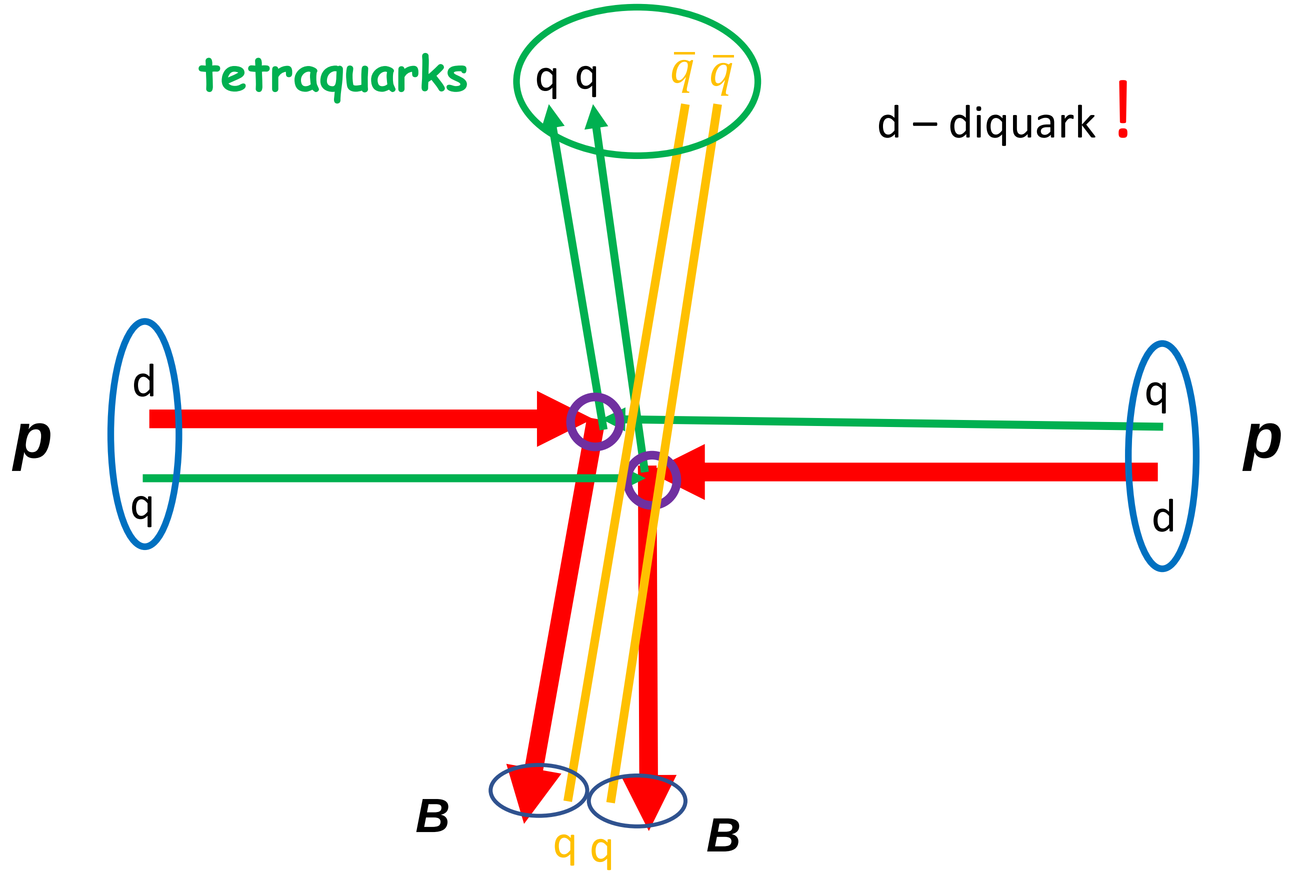
Exotic states production

pp - reactions with direct pentaquarks production



Exotic states production

pp - reactions with direct tetraquarks production



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