“High p_T physics at $\sqrt{s_{NN}} < 10$ GeV: Fundamental problems and its solution”

S.S. Shimanskiy (JINR)

PLAN

1. Fundamental problems and why $\sqrt{s_{NN}} < 10\ GeV$

2. Unique experimental features

3. How can be resolved these problems

Fundamental problems and why $\sqrt{s_{NN}} < 10\ GeV$

SPIN IN PARTICLE PHYSICS

ELLIOT LEADER
Imperial College, London

Preface

In purely hadronic physics, too, there are tantalizing questions regarding spin dependence. There exists a whole array of semi-inclusive experiments like pp —▶ πX with a transversely polarized proton beam or target, or pp —▶ hyperon + X, with an unpolarized initial state in which huge hyperon spin asymmetries or polarizations — at the 30%-40% level! — are observed. These experiments are very hard to explain within the framework of QCD. The asymmetries all vanish at the partonic level and one has to invoke soft, non-perturbative mechanisms. All such mechanisms predict that the asymmetries must die out as the momentum transfer increases, yet there is no sign in the present data of such a decrease.

In exclusive reactions like pp —▶ pp the disagreement between the data on the analysing power at large momentum transfer and the naive QCD asymptotic predictions is even more severe, but here at least there is an escape clause: the theory of exclusive reactions in QCD is horrendously difficult.

A.Krisch, DSPIN 2009

SUMMARY

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.).

And extension into non polarized phenomena!

A.Krisch, DSPIN 2009

PHYSICAL REVIEW D VOLUME 23, NUMBER 3 1 FEBRUARY 1981

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

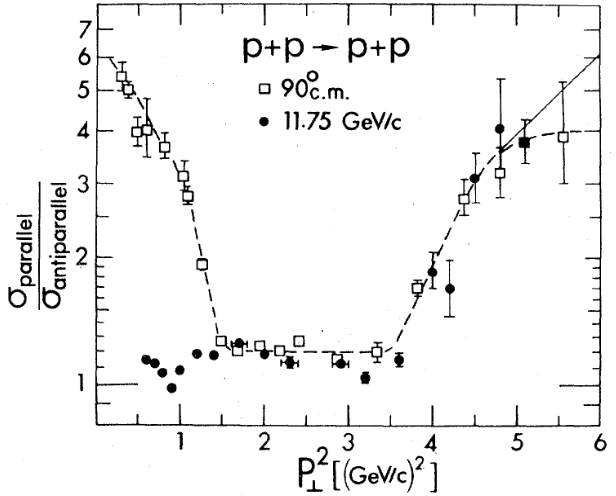


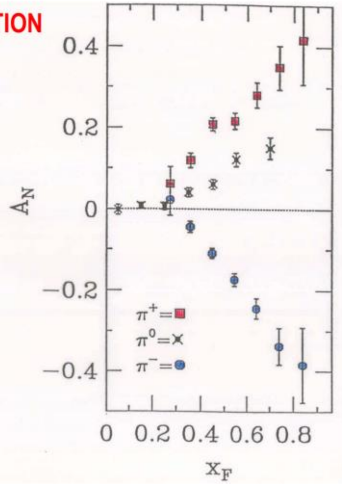
FIG. 3. Plot of the ratio of the spin-parallel to spin-antiparallel differential cross sections, as a function of $P_{\perp}^2$, for p-p elastic scattering. The squares are the fixed-angle data at $90°_{c.m.}$, with the incident energy varied. The circles are data (Refs. 5, 11) with the momentum held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

p_T ~ 2 GeV/c region

INCLUSIVE PION PRODUCTION

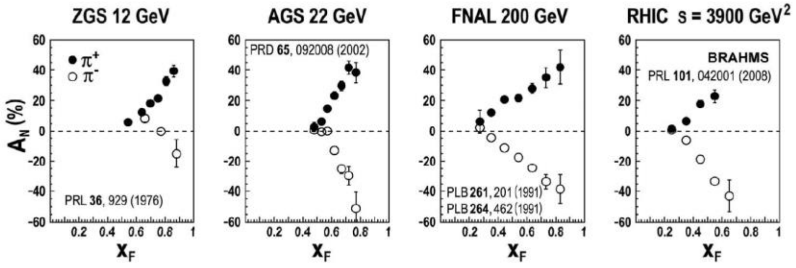
200 GeV Polarized Proton Beam
from Polarized Hyperon Decay
1990s Fermilab E-704
Yokosawa *et al.*
Phys Lett B264, 462 (1991)

A_n ~ 40%
QCD said A_n ~ 0



INCLUSIVE PION ASYMMETRY IN PROTON-PROTON COLLISIONS

C. Aidala SPIN 2008 Proceeding and CERN Courier June 2009



VOLUME 43, NUMBER 14 PHYSICAL REVIEW LETTERS 1 OCTOBER 1979

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

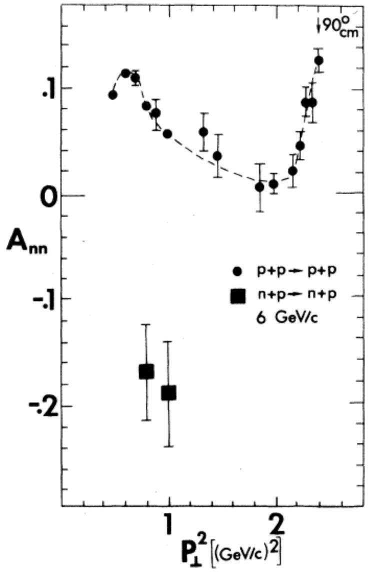


FIG. 2. The spin-spin correlation parameter, A_{nn}, for pure-initial-spin-state nucleon-nucleon elastic scattering at 6 GeV/c is plotted against the square of the transverse momentum. The proton-proton and neutron-proton data are quite different.

INCLUSIVE HYPERON POLARIZATION

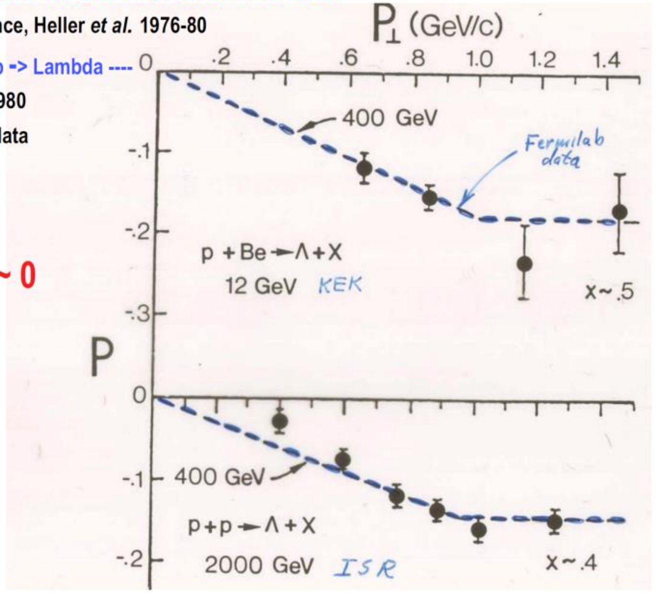
Devlin, Pondrum, Bunce, Heller *et al.* 1976-80

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

Plot by Heller ~1980
with KEK & ISR data

P ~ 15-20 %

QCD says P ~ 0



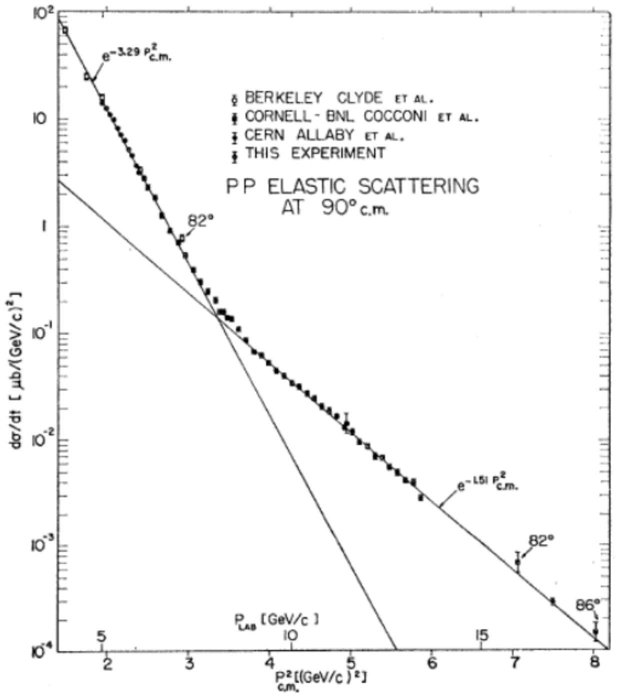
Non-polarized particle beams

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

pp -> pp (90^0)

C. Baglin et al., Phys.Lett. B, vol.225, N3, 296-300, 1989

$$R = \frac{\sigma(pp \to pp)}{\sigma(\bar{p}p \to \bar{p}p)}(90^o\, c.m.)$$



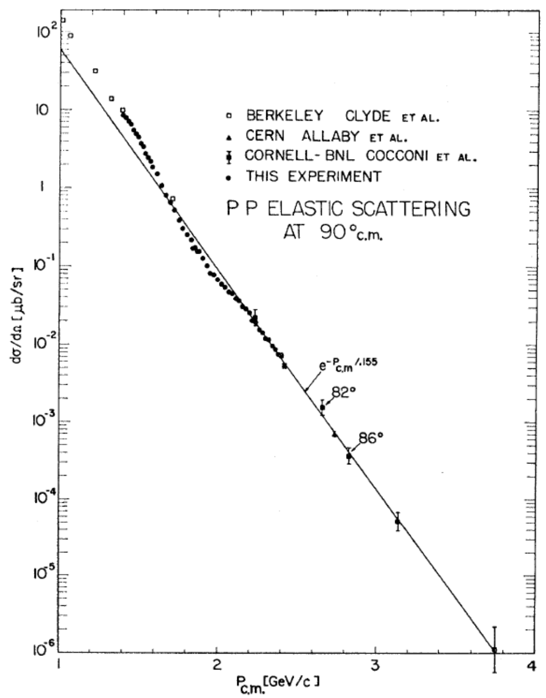
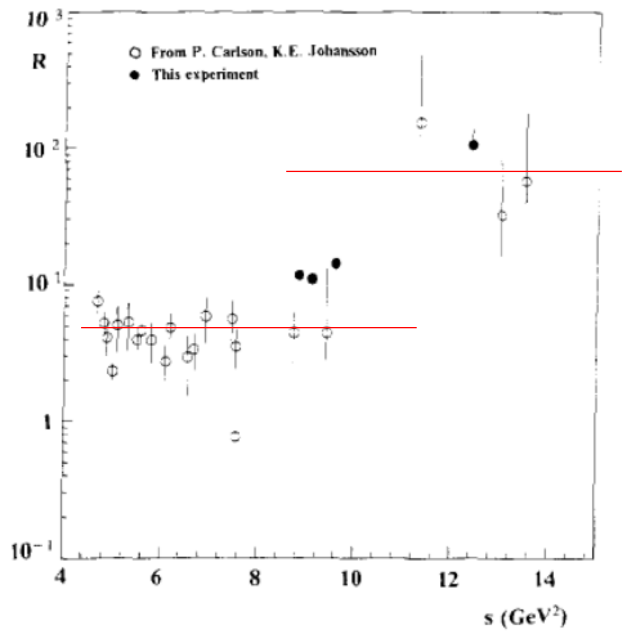


FIG. 9. Plot of $d\sigma/dt$ versus $\beta^2 P_\perp^2$ for all high-energy proton-proton elastic scattering. Other data (Refs. 13, 20, 22, 23), are also plotted. The lines drawn are straight line fits to the data.



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

p_T ~ 2 GeV/c region

Cumulative processes

R_{AA}, v_2, p/π …?

Schroeder L.S. et al.
Phys. Rev. Lett. 1979. V. 43, n. 24. P. 1787

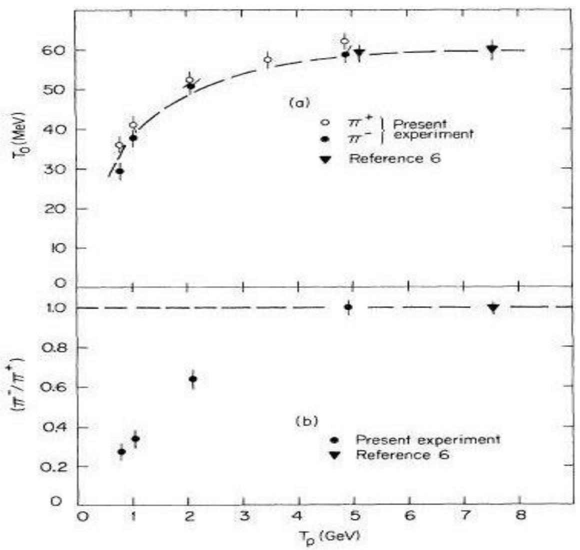


FIG. 1. Energy dependence of (a) T_0 parameter for pions, and (b) the π^-/π^+ ratio at 180° obtained by integrating each spectra up to 100 MeV for p-Cu collisions from 0.8 to 4.89 GeV. The dashed curve in both cases refers to the predictions of the "effective-target" model (Refs. 3 and 4).

Leksin G.A.
Physics of Atomic Nuclei, Vol. 65, No. 11, 2002, pp. 1985–1994

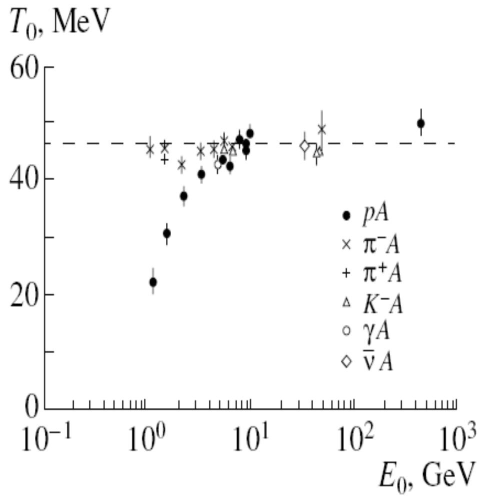
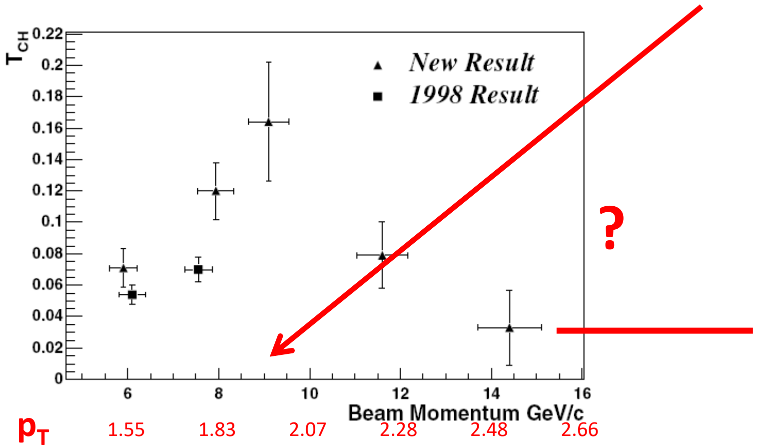


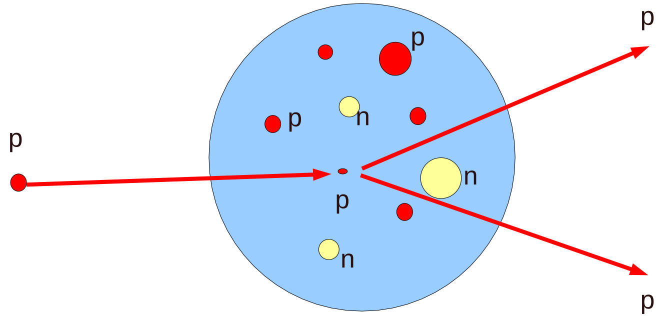
Fig. 5. Dependence of the slope parameter T_0 for the invariant function of the protons escaping under the action of $p, \pi^{\pm}, K^-, \gamma, \bar{\nu}$ with various energies E_0; the escape angle is 120° in the laboratory frame.

Color (nuclear) transparency

p_T ~ 2 GeV/c region



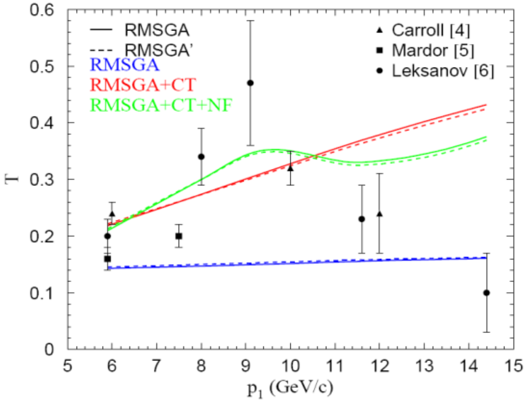
$$T = \frac{\frac{d\sigma}{dt}(p + "p" \rightarrow p + p)}{Z\frac{d\sigma}{dt}(p + p \rightarrow p + p)}$$



7, NUMBER 21 PHYSICAL REVIEW LETTERS 19 NOVEMBER

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

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



DIQUARK COMPONENT

Can be as candidate for subcomponent of hadrons

Volume 8, number 3 PHYSICS LETTERS 1 February 1964

Multiquark states have been discussed since the 1st page of the quark model

A SCHEMATIC MODEL OF BARYONS AND MESONS *

M. GELL-MANN
California Institute of Technology, Pasadena, California

Received 4 January 1964

If we assume that the strong interactions of baryons and mesons are correctly described in terms of the broken "eightfold way" [1-3], we are tempted to look for some fundamental explanation of the situation. A highly promised approach is the purely dynamical "bootstrap" model for all the strongly interacting particles within which one may try to derive isotopic spin and strangeness conservation and broken eightfold symmetry from self-consistency alone [4]. Of course, with only strong interactions, the orientation of the asymmetry in the unitary space cannot be specified; one hopes that in some way the selection of specific components of the F-spin by electromagnetism and the weak interactions determines the choice of isotopic spin and hypercharge directions.

Even if we consider the scattering amplitudes of strongly interacting particles on the mass shell only and treat the matrix elements of the weak, electromagnetic, and gravitational interactions by means

ber $n_t - n_{\bar{t}}$ would be zero for all known baryons and mesons. The most interesting example of such a model is one in which the triplet has spin $\frac{1}{2}$ and $z = -1$, so that the four particles d^-, s^-, u^0 and b^0 exhibit a parallel with the leptons.

A simpler and more elegant scheme can be constructed if we allow non-integral values for the charges. We can dispense entirely with the basic baryon b if we assign to the triplet t the following properties: spin $\frac{1}{2}$, $z = -\frac{1}{3}$, and baryon number $\frac{1}{3}$. We then refer to the members $u^{\frac{2}{3}}$, $d^{-\frac{1}{3}}$, and $s^{-\frac{1}{3}}$ of the triplet as "quarks" [6] q and the members of the anti-triplet as anti-quarks $\bar{q}$. Baryons can now be constructed from quarks by using the combinations (qqq), $(qqqq\bar{q})$, etc., while mesons are made out of $(q\bar{q})$, $(qq\bar{q}\bar{q})$, etc. It is assuming that the lowest baryon configuration (qqq) gives just the representations **1**, **8**, and **10** that have been observed, while the lowest meson configuration $(q\bar{q})$ similarly gives just **1** and **8**.

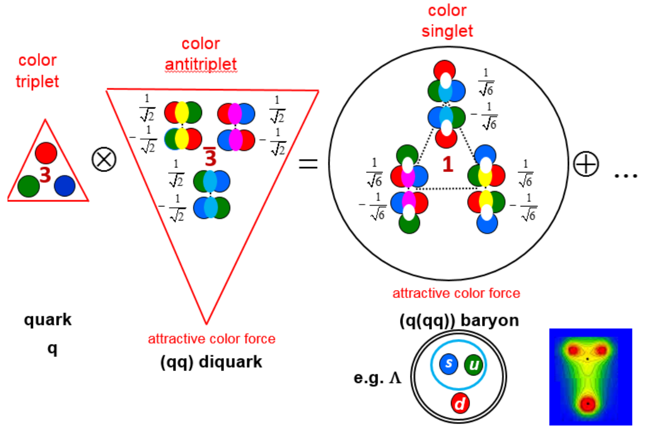
that it would never have been detected. A search for stable quarks of charge $-\frac{1}{3}$ or $+\frac{2}{3}$ and/or stable di-quarks of charge $-\frac{2}{3}$ or $+\frac{1}{3}$ or $+\frac{4}{3}$ at the highest energy accelerators would help to reassure us of the non-existence of real quarks.

Hadrons from diquarks?

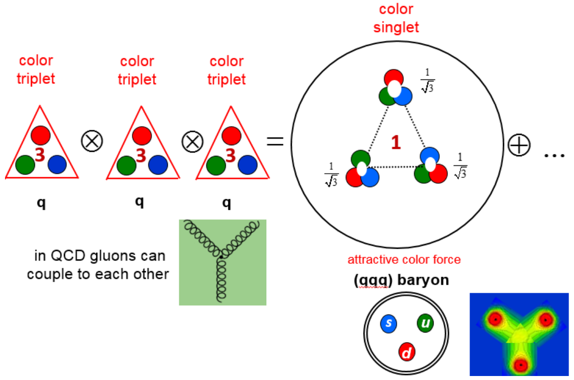
STATIC

Still an open question!

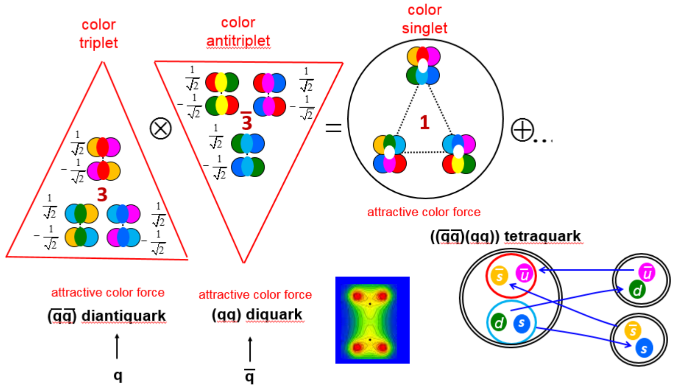
Role of diquarks in building hadrons?

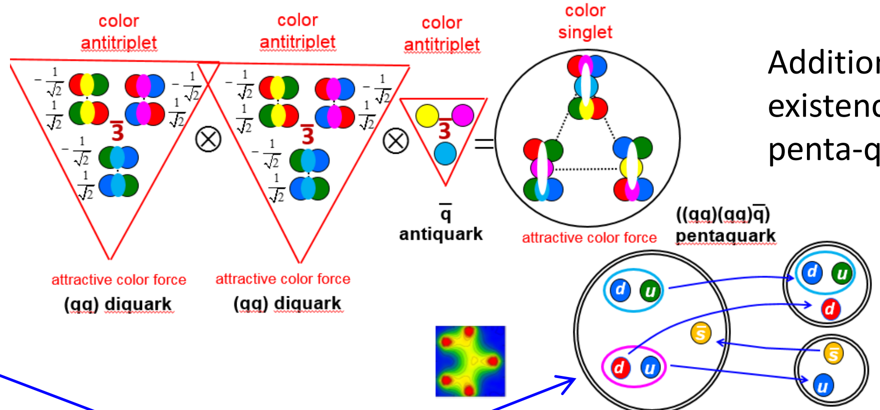


vs.



Light and heavy baryon spectroscopy is sensitive to this question





Additional motivation for existence of tetra- and penta-quarks.

Does effective mechanism to suppress rapid fall-apart exist?

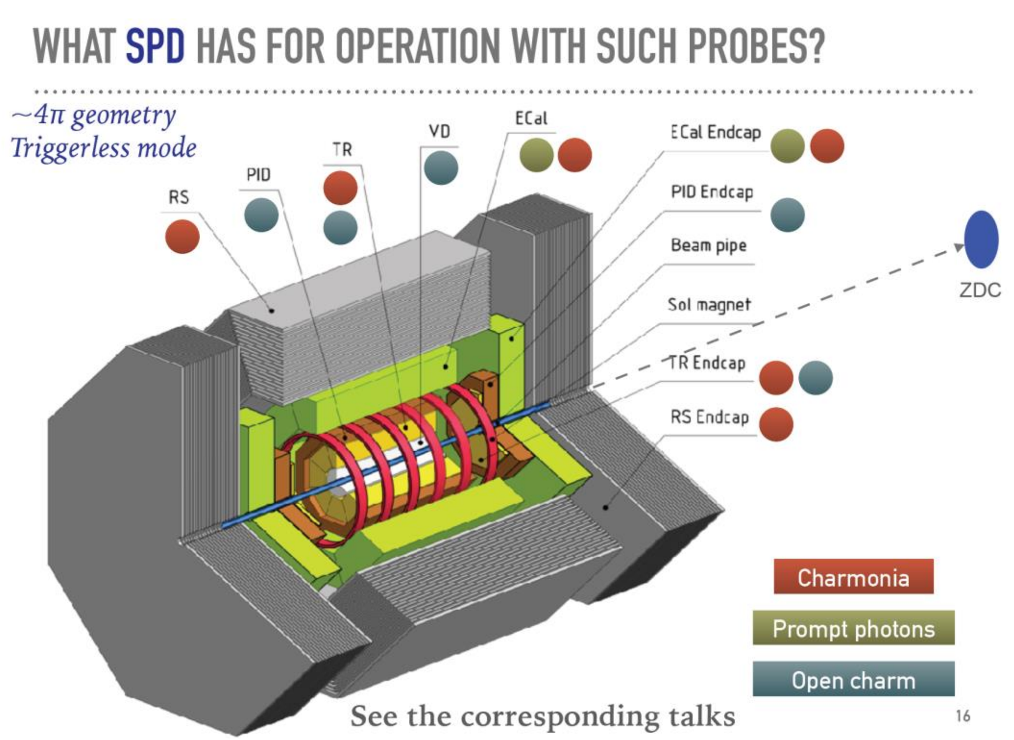
Exotic Hadrons,
Dubna, Sep.18,2018
Tomasz Skwarnicki

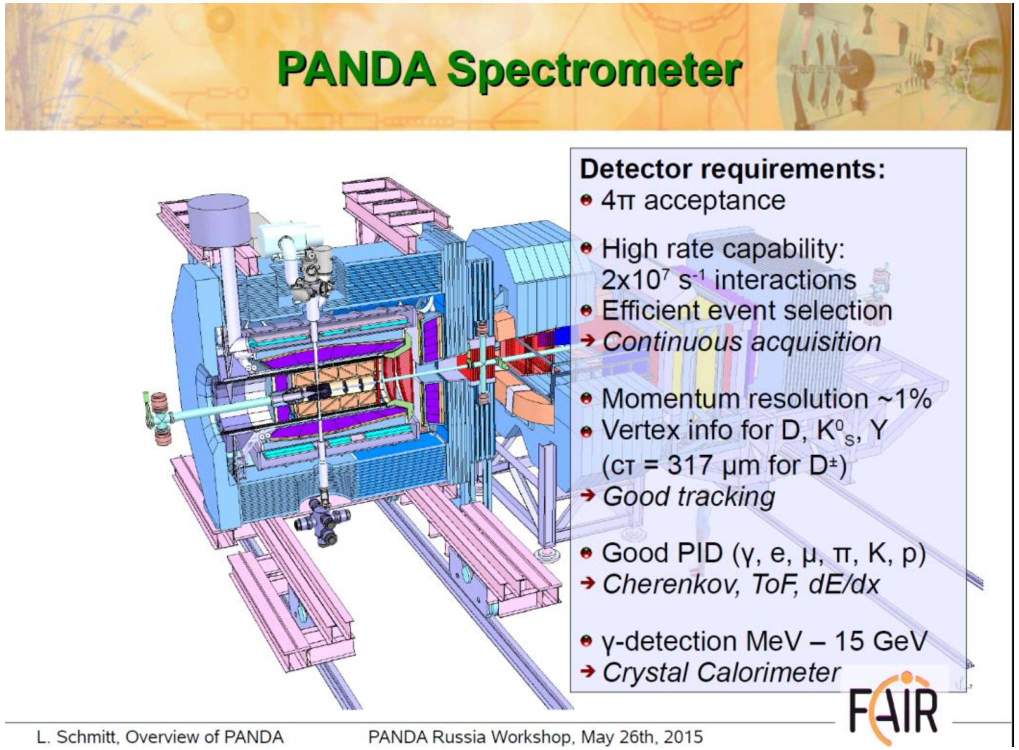
All these phenomena are happened in the $\sqrt{s_{NN}} < 10\ GeV$

No explanations up to now!

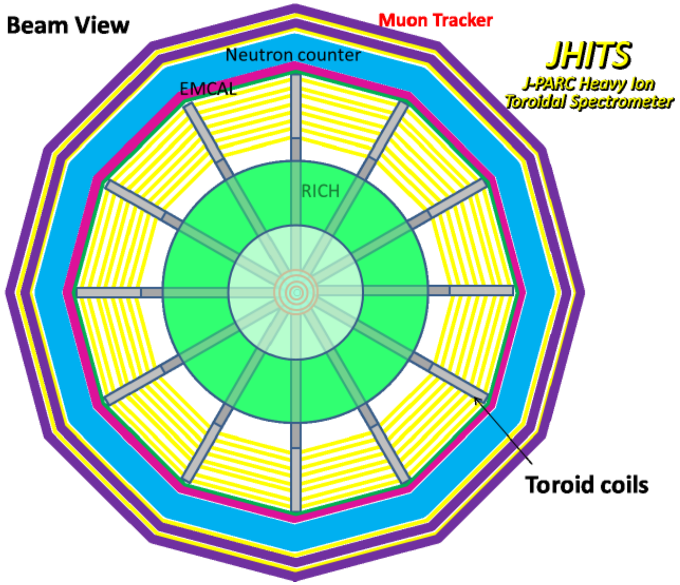
Unique experimental features

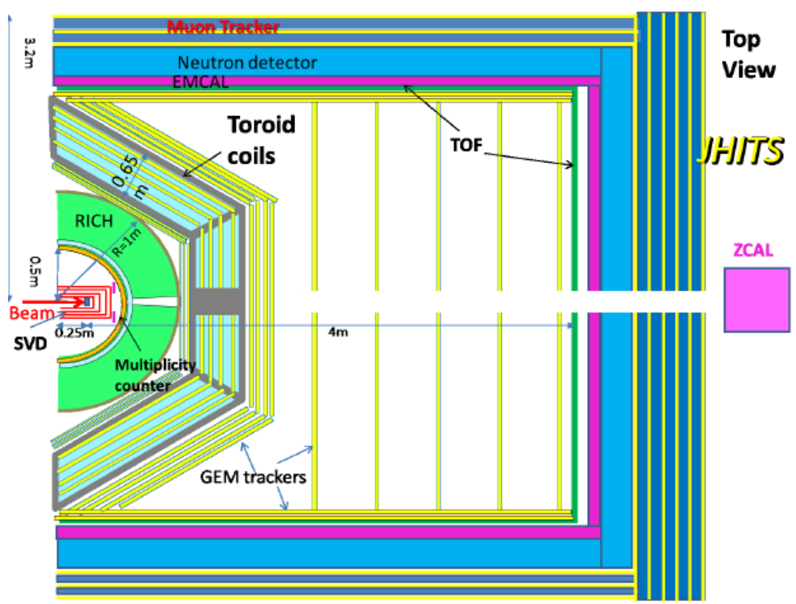
That will open possibility to provide unique experiments





[Studies of extremely dense matter in heavy-ion collisions at J-PARC](), [J-PARC-HI Collaboration]() (by H. Sako for the collaboration), 2019, 4 pp. Published in **Nucl.Phys. A982 (2019) 959-962**





Main advantages

The unique beams: – wide range of kind of the beam particles (especially antiproton and polarization) and $\Delta p/p$ up to 10^{-5}.

The unique detectors: $\Delta\Omega \sim 4\pi$ (exclusive reactions, correlations, backward range); detection all kinds of particles (especially neutron); working at luminosity up to 10^{30} - 10^{32} $cm^{-2}\ s^{-1}$ (the rare event can be investigated); PID – close to full energy range.

Some unique features for NICA

- Spin transparency mode in the NICA collider provide unique opportunity for efficient spin manipulation of any particle species (*p*, *d*, ^3He, …) in any orbit place without affecting of the collider orbital characteristics.
- Both vertical and longitudinal directions of the beam polarization in MPD and SPD detectors are available.
- Spin flipping system allows one to carry out high quality experiments with polarized proton and deuteron beams.

Some unique features for NICA

Working with spin-flippers at NICA

a) new ring fill modes (all bunches with the same polarization in both rings) and the work (sequential switching-on of the spin-flippers in the rings):

1st ring	+++...	|xxx|	- - -...	|----|	- - -...	|xxx|	+++	|----|	+++...
2nd ring	+++...	|----|	+++...	|xxx|	- - -...	|----|	- - -	|xxx|	+++...
	(+ +)		(- +)		(- -)		(+ -)		(+ +)

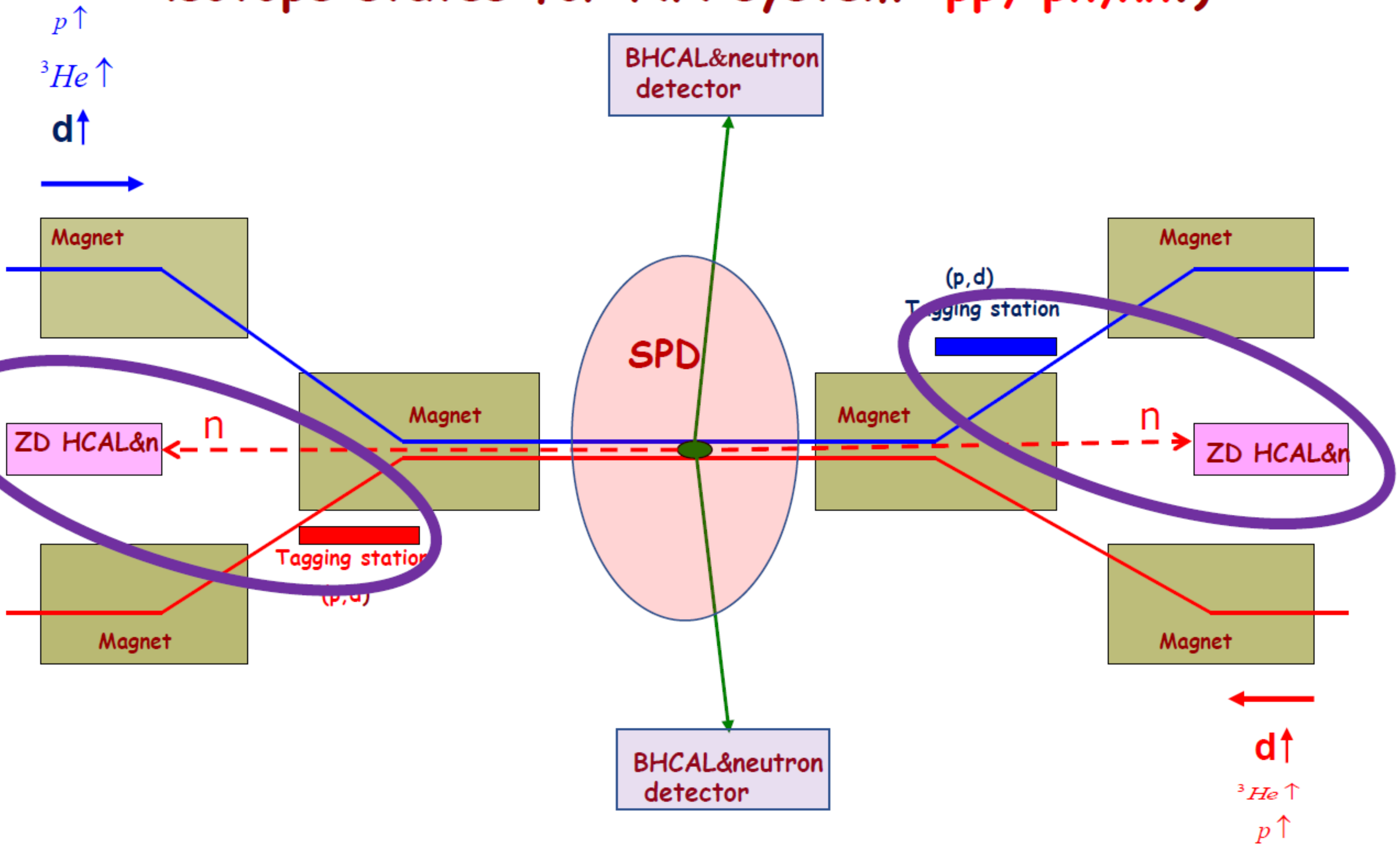
|xxx| - spin-flipper switching-on, no data taking

|----| - spin-flipper switching-off, no data taking

b) there is no problem with measuring interbunch luminosity, no problem with different polarization for different modes of the source!

Some unique features for NICA

NICA Collision place for SPIN physics (deuteron and other beams, the first time all isotope states for NN system: pp, pn,nn.)



The tagging stations can be used as polarimeter!

DIQUARK DYNAMIC MANIFESTATION

Manifestation of Diquark

arXiv:1007.4705v5 [hep-ph] 25 Sep 2010
&Phys.Rev. C83 (2011) 054606
Carlos Granados and Misak Sargsian

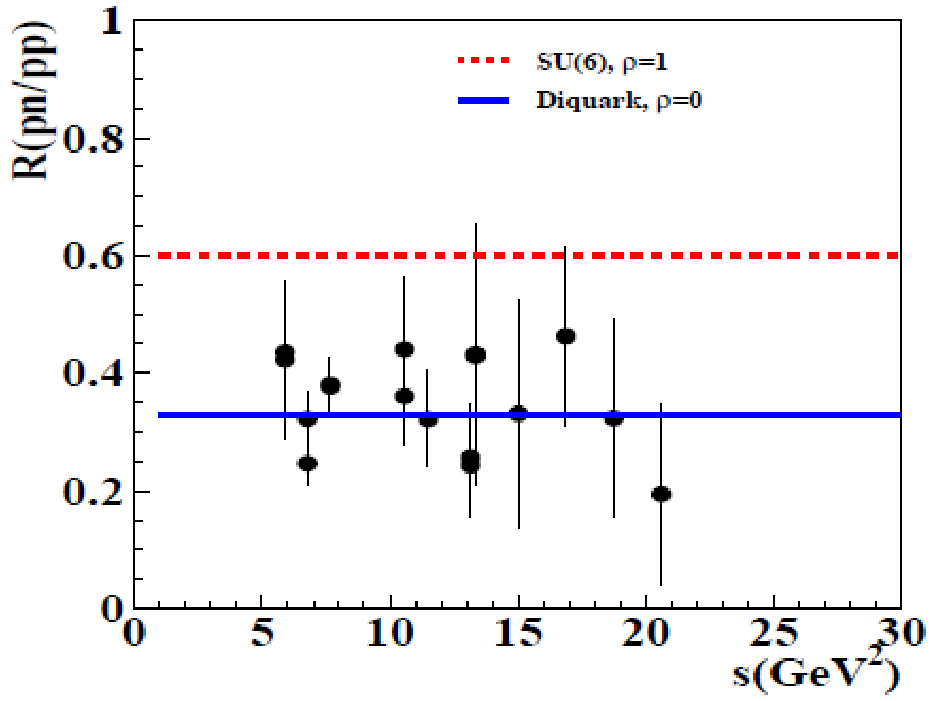
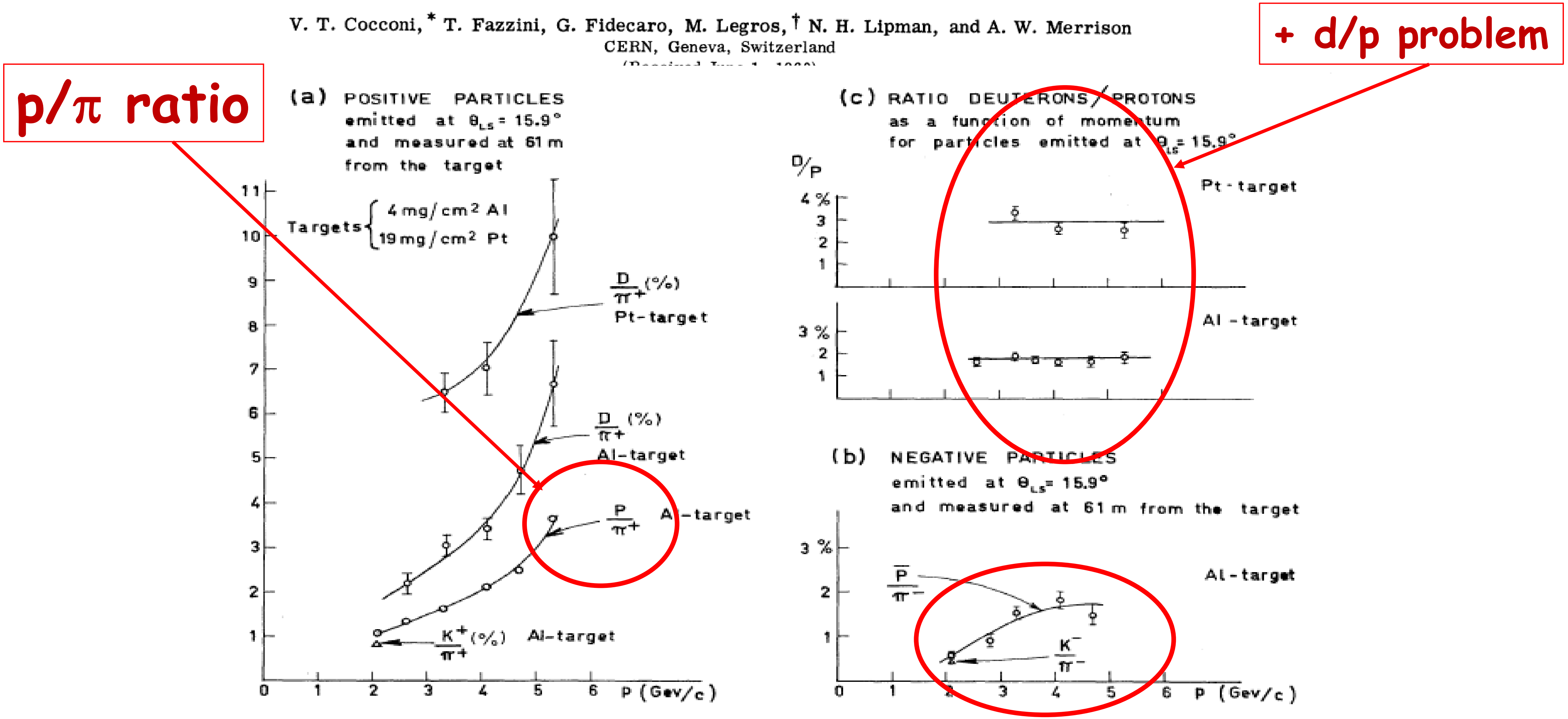


FIG. 2: (Color online) Ratio of the $pn \to pn$ to $pp \to pp$ elastic differential cross sections as a function of s at $\theta^N_{c.m.} = 90^0$.

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



V.T. Kim

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

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

p/π ratio

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.

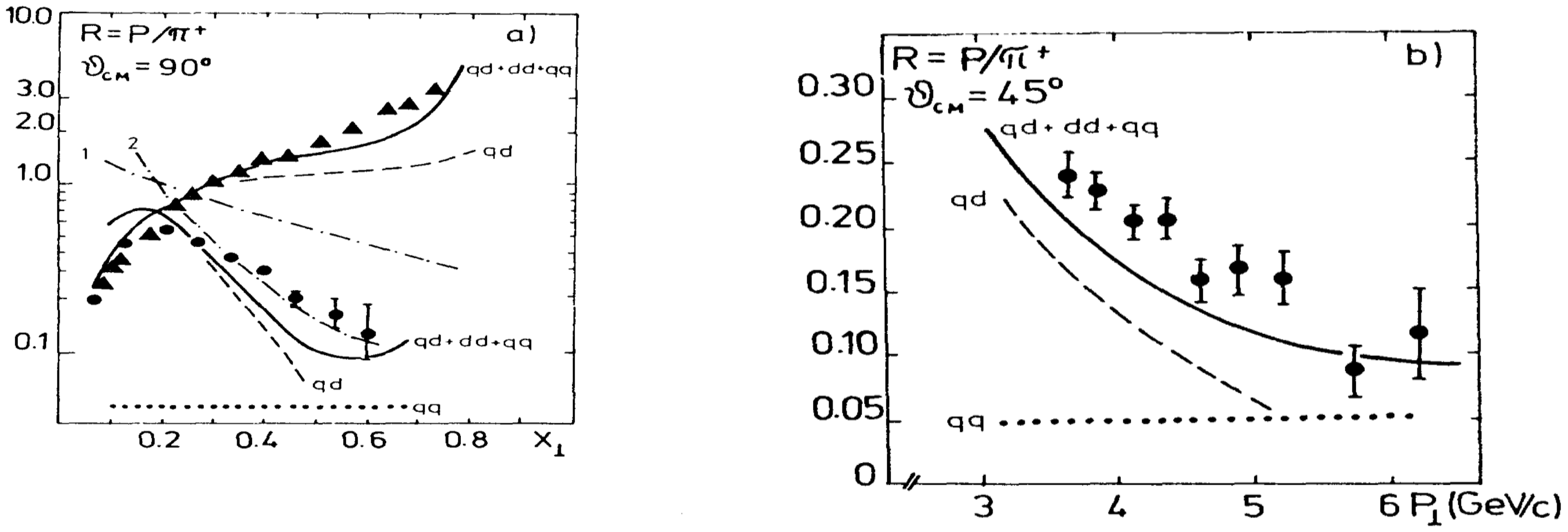
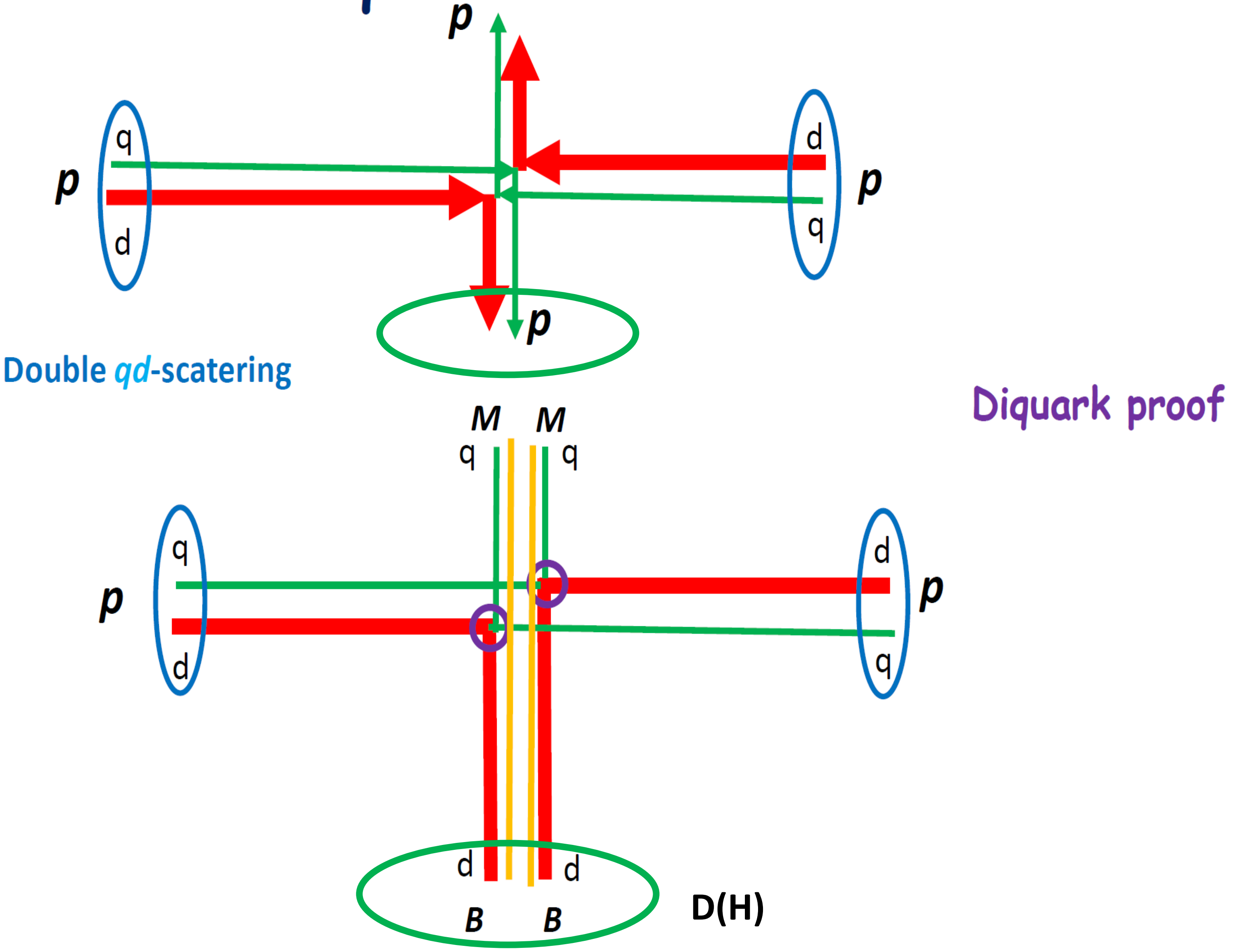


Fig. 1. $R = p/\pi^+$ is the particle yield ratio in the pp-collisions.
a) $\vartheta_{CM} = 90°$: • the FNAL data[1] at $\sqrt{s} = 23.4$ GeV ($E = 300$ GeV); ▲ the IHEP (Serpukhov) data[2] at $\sqrt{s} = 11.5$ GeV ($E = 70$ GeV).
b) $\vartheta_{CM} = 45°$: • the CERN ISR data[3] at $\sqrt{s} = 62$ 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).

Ratio d/p

Kim's mechanisms in exclusive reactions

pp - > pp + X, pp -> D(H) + X reactions with diquarks



How can be resolved these problems?

NN – interactions mainly

From the inclusive experiments to the correlations and the exclusive experiments.

We haven't the theory but we will have new experimental set ups.

NN Elastic scattering with polarized deuteron beams at NICA:

$$p\uparrow + p\uparrow \to p + p$$ for calibration

$$p\uparrow + n\uparrow \to p + n$$

$$n\uparrow + n\uparrow \to n + n$$

New data!

By the way we will have the counting rules verification!

pd, nd and dd – too!

Exclusive NN study at x_T ~ 1
Hadron reactions when all particles in high p_T region

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

PANDA

B (p,n,Λ, Δ...), M (π, K, μ...)

Mechanisms of hyperons polarization

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

isotopic symmetry (quark universality) studies, p_T ~ 2 GeV/c anomaly

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

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

Detail vertexes studies and spin structure of the interaction vertex:

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

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

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

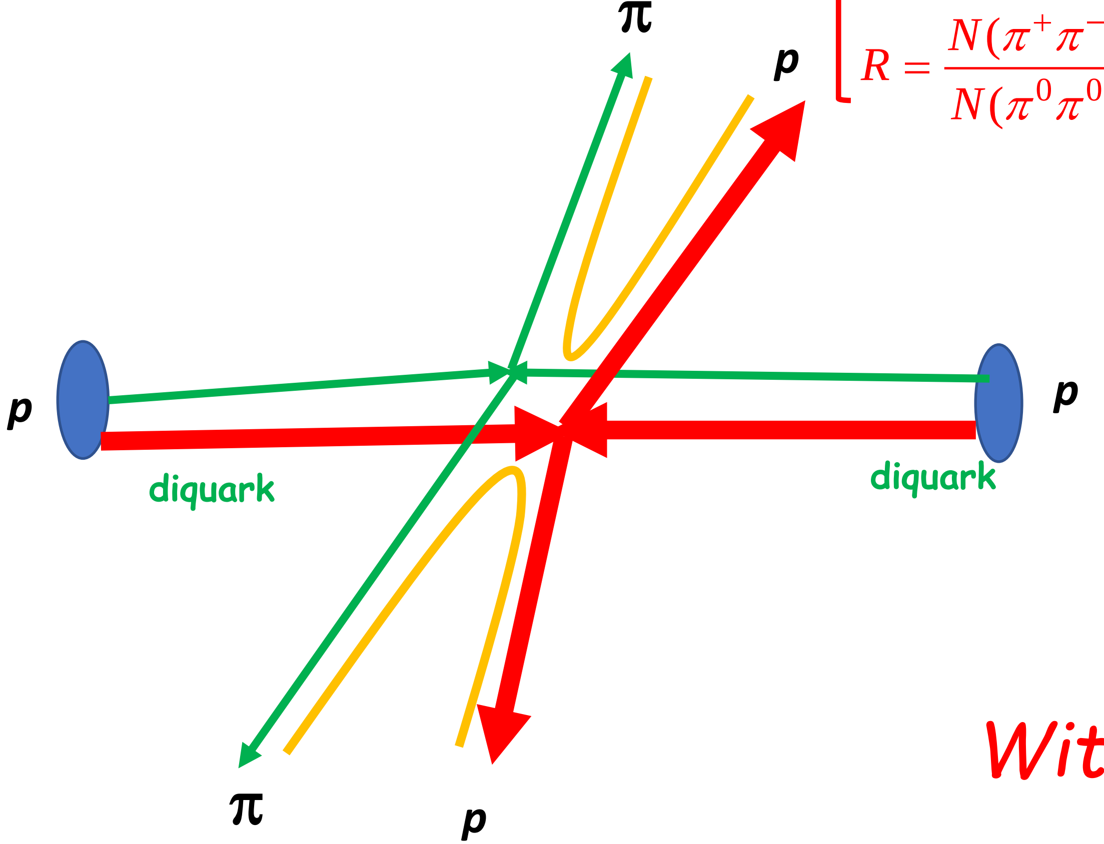
High p_T exclusive inelastic reactions -> MPI

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

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

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

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



Diquark (S=0)

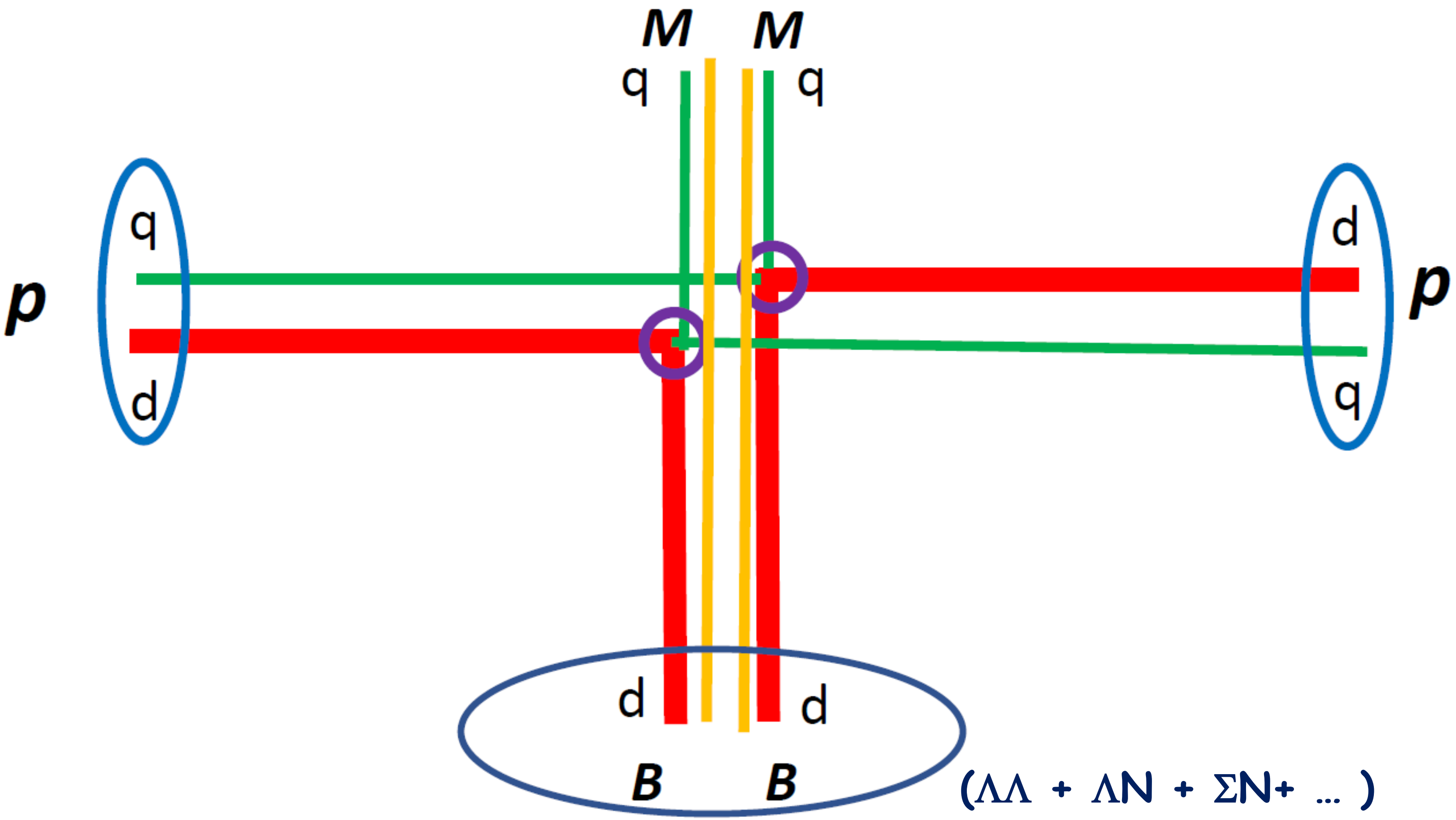
$$A_{n(pp)} \to 0$$

With out $q\bar{q}$ pair $A_{(\Delta^+)(\Delta^+)}$

pp -> D(H + ΛN + ΣN) + … reactions with diquarks

Double *qd*-scatering

Diquark proof

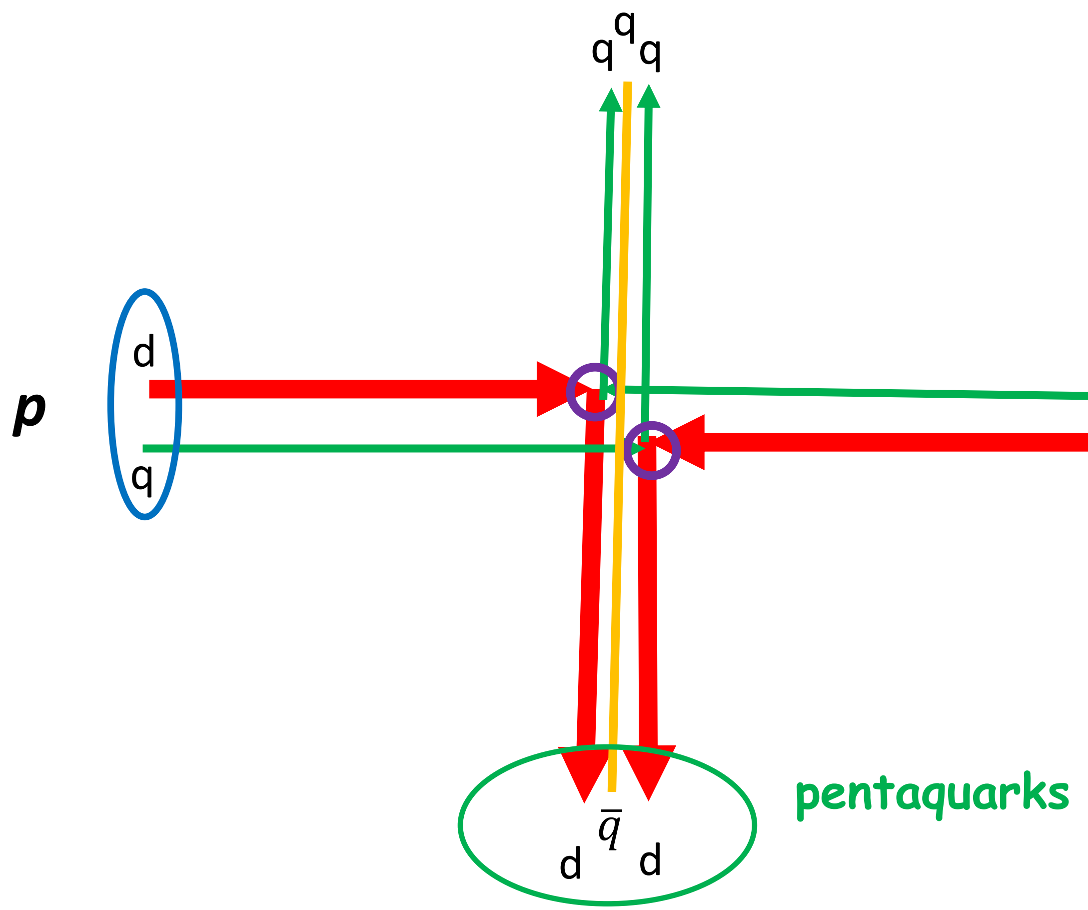


(ΛΛ + ΛN + ΣN+ …)

Exotic states and flavor universality

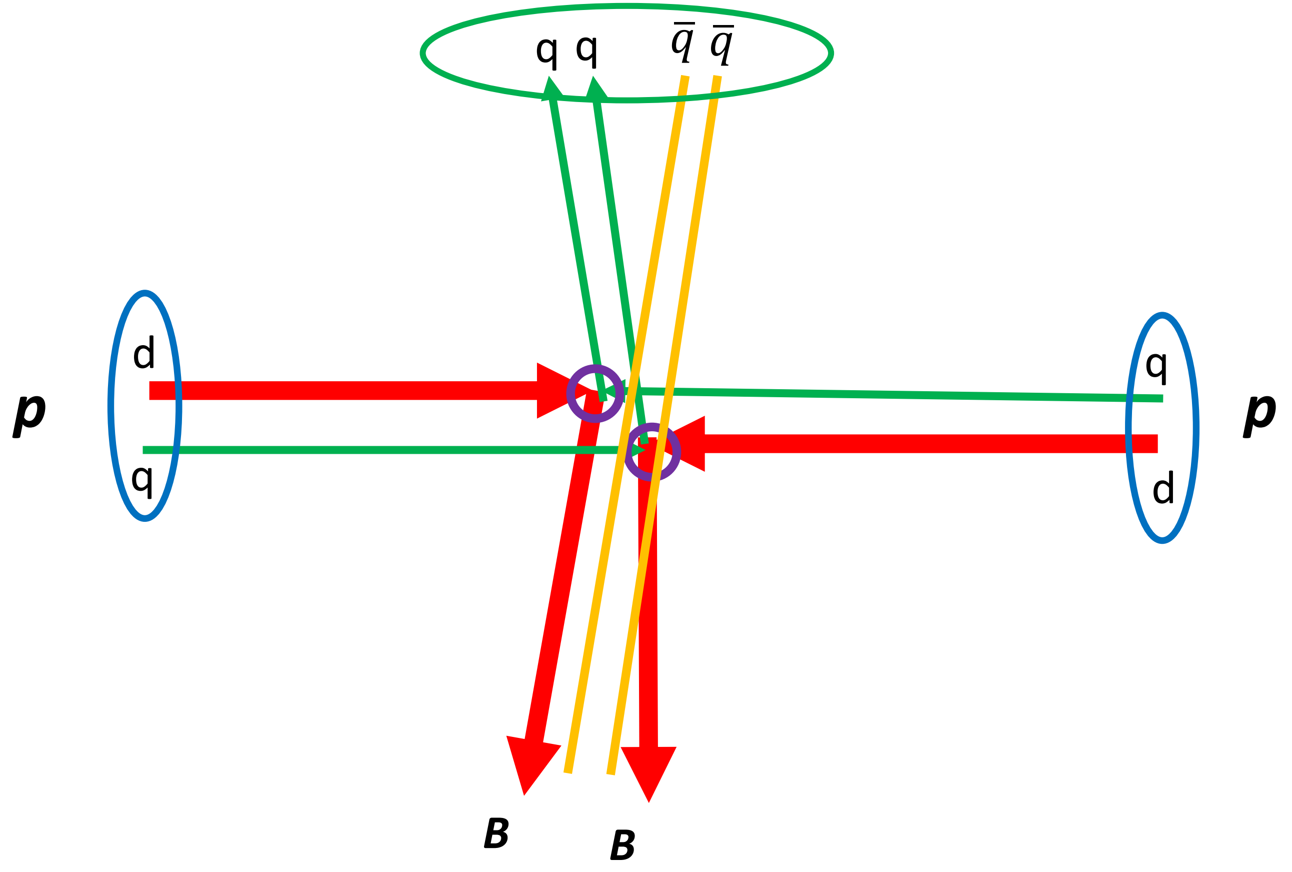
Exotic states production

pp - reactions with pentaquarks production

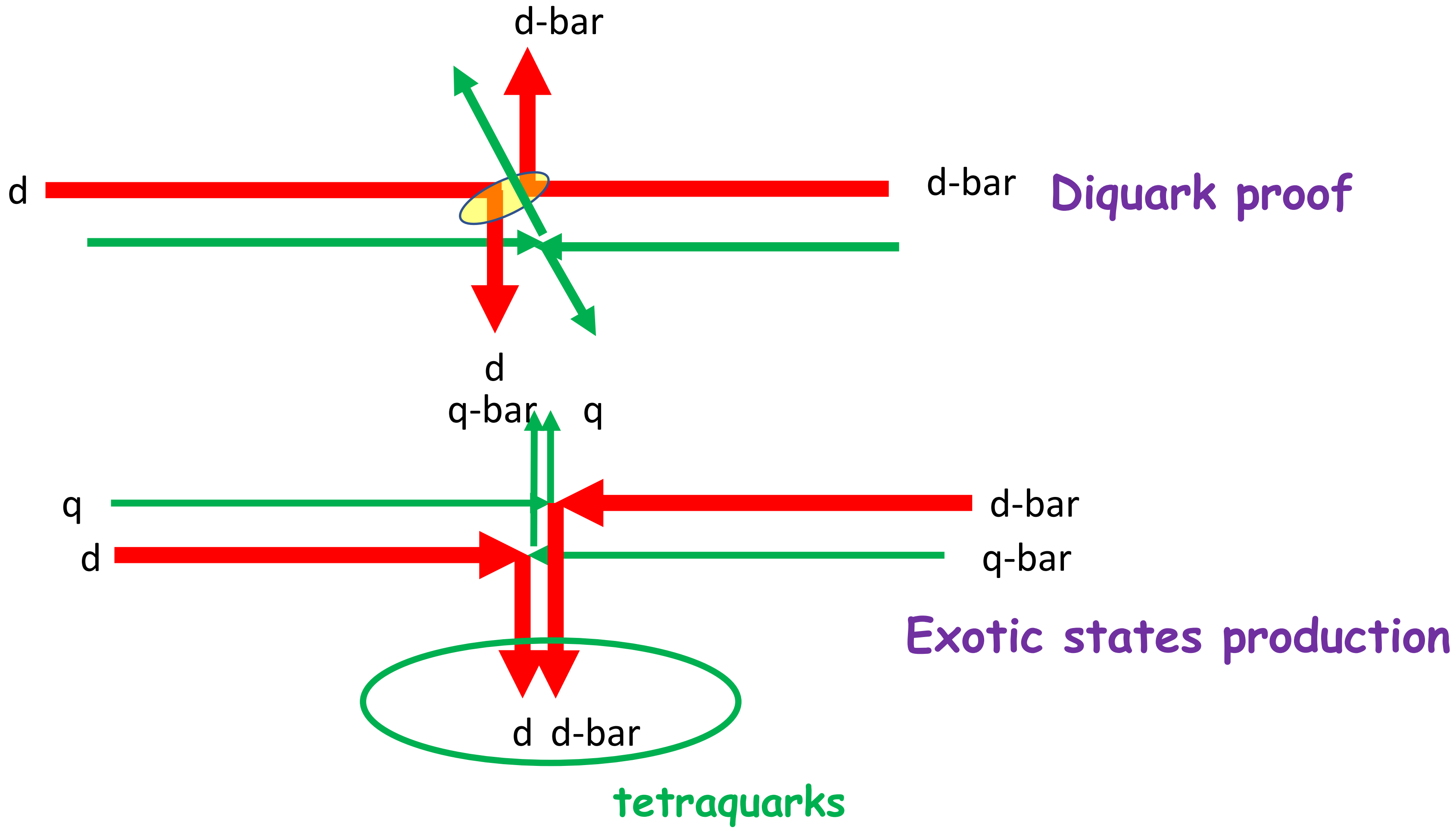


Exotic states production

pp - reactions with tetraquarks production



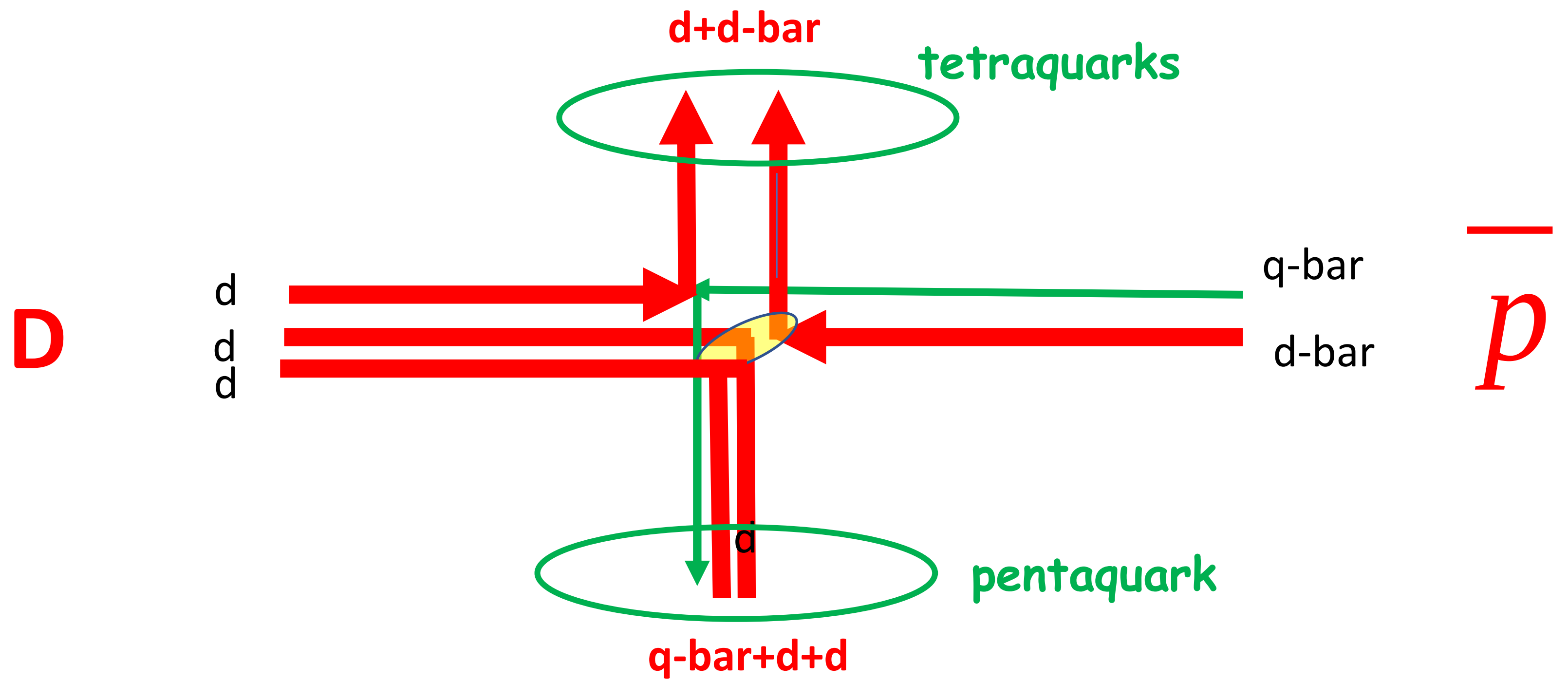
PANDA
Direct reaction to tetraquarks production in $\bar{p}p$



PANDA

Exotic states production

$\bar{p}d$ - reaction with tetraquarks +pentaquark production



MULTIQUARK(MULTINUCLEON) COMPONENT

CUMULATIVE PROCESSES

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)

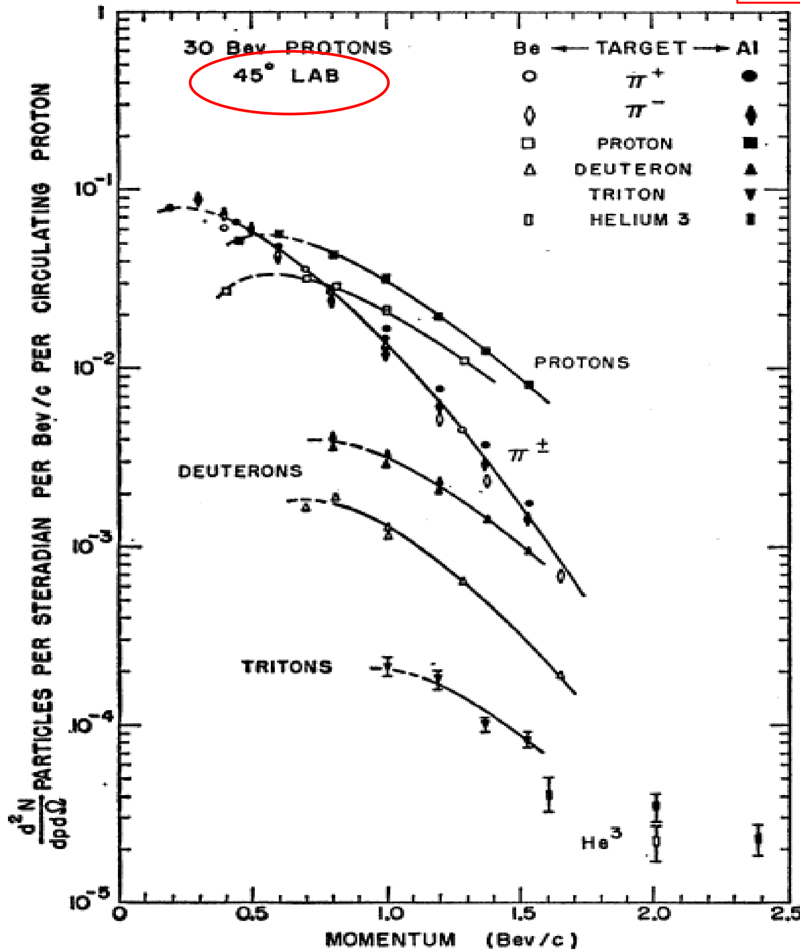


Fig. 3. Momentum spectra of particles emitted at 45° from aluminum and beryllium targets when struck by 30-Bev protons. Tritons from Be were not measured. For general remarks refer to Fig. 2 caption.

+ d/p problem, cum. Region ~0.25

p/π ratio ~ 20

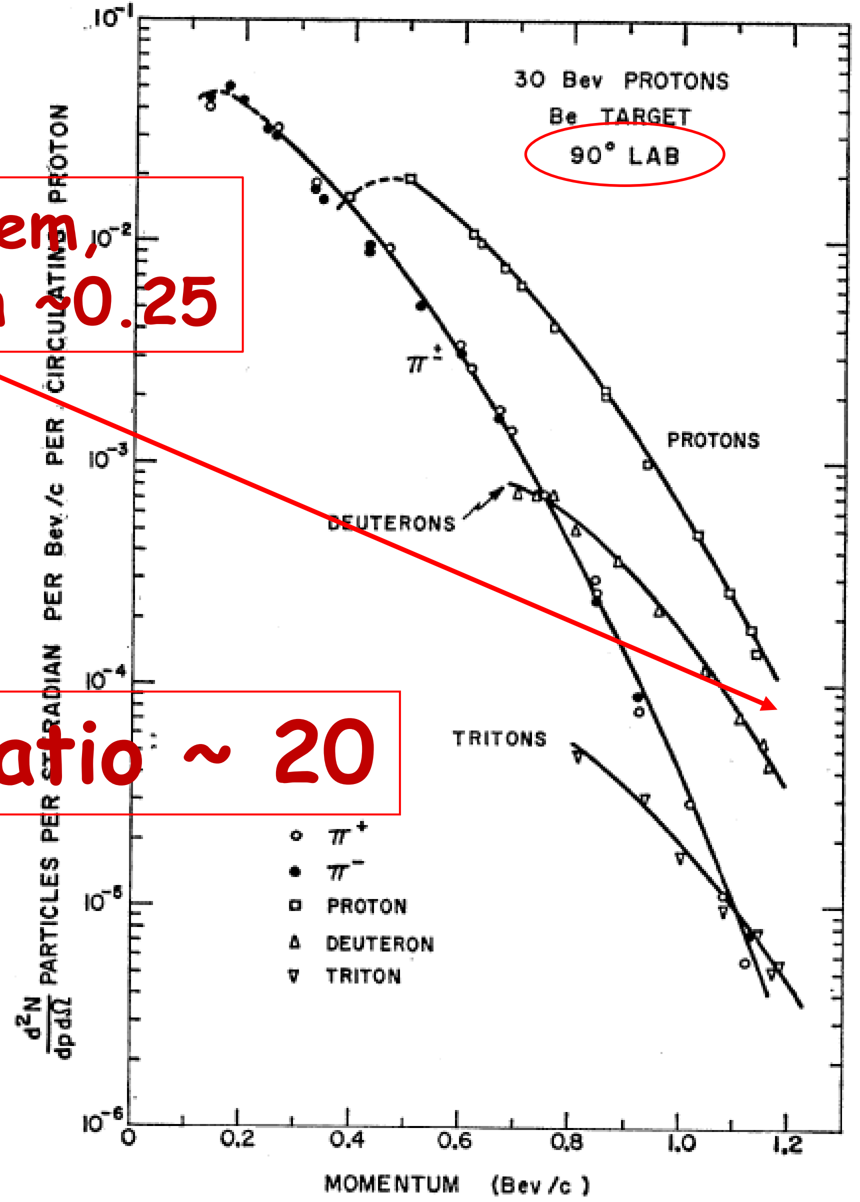
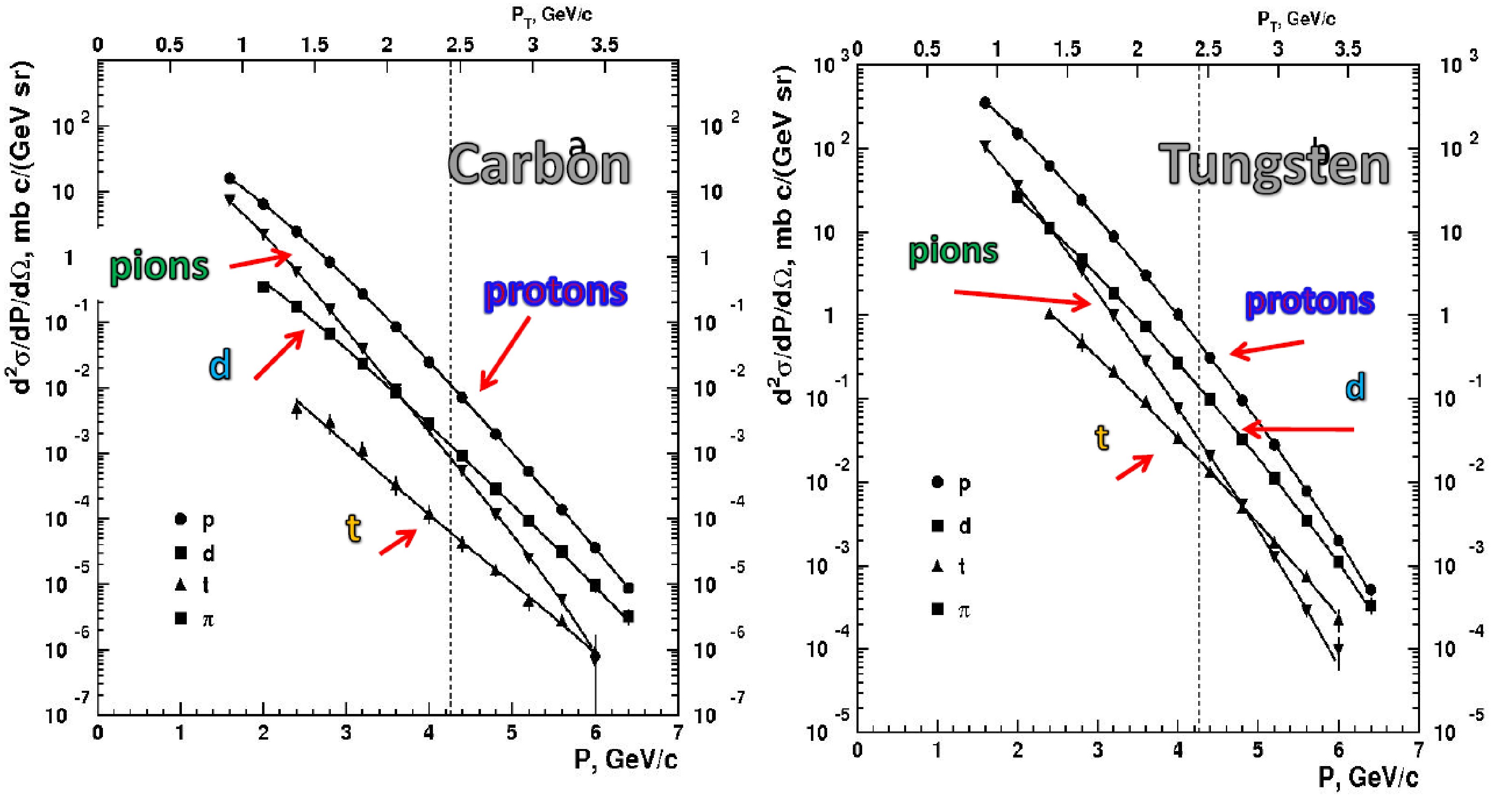


Fig. 2. Momentum spectrum of particles emitted at 90° from a beryllium target struck by 30-Bev protons. The ordinate is the number of particles produced at the target per steradian per Bev/c per circulating proton. The dashed portions of the curves indicate regions where the corrections due to multiple scattering exceed 15%. At the time these data were taken no effort was made to detect He^3.

$p + A \rightarrow c\ (35^0_{lab}) + X$ **SPIN data** N.N. Antonov et al., *JETP Letters*, Vol.101, No.10, pp.670-673(2015)

E_p=50 GeV



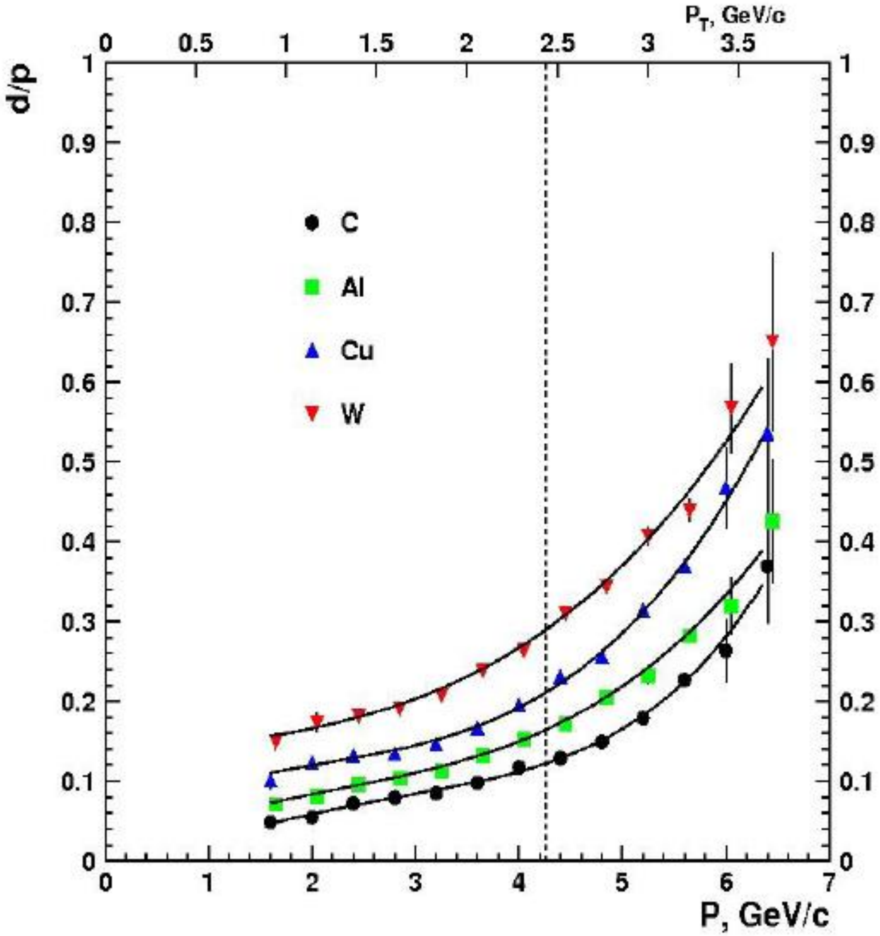
Invariant function found for positive pion, proton, deuteron and triton.

The vertical dashed lines indicate the kinematical limit for elastic nucleon–nucleon scattering. The upper horizontal scale shows values of the transverse momentum p_T .

Ratio d/p

SPIN data

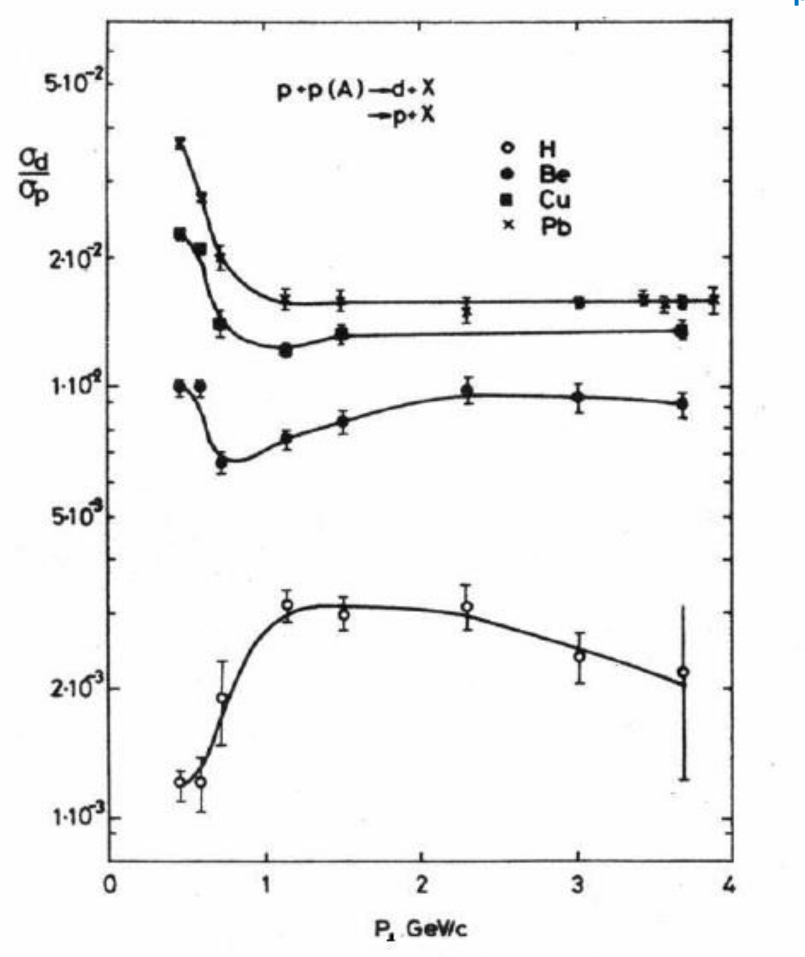
p + A -> c (35^0_{lab}) + X
E_p=50 GeV



FODS data

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

p + A -> c (90^0_{cms}) + X
E_p=70 GeV



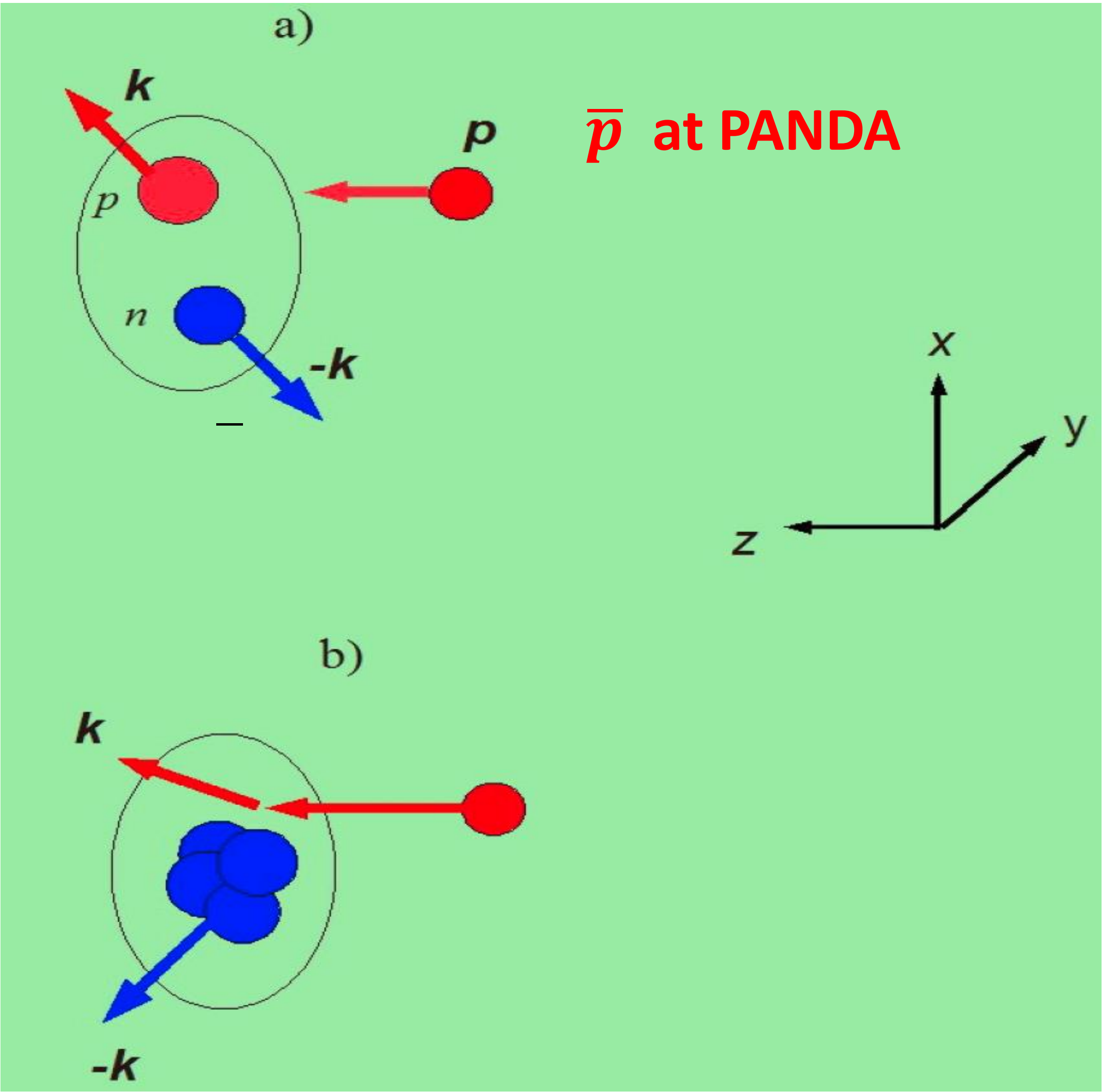
Knot out cold dense nuclear configurations

SRC configuration

<B> ~ 1

<B> ?

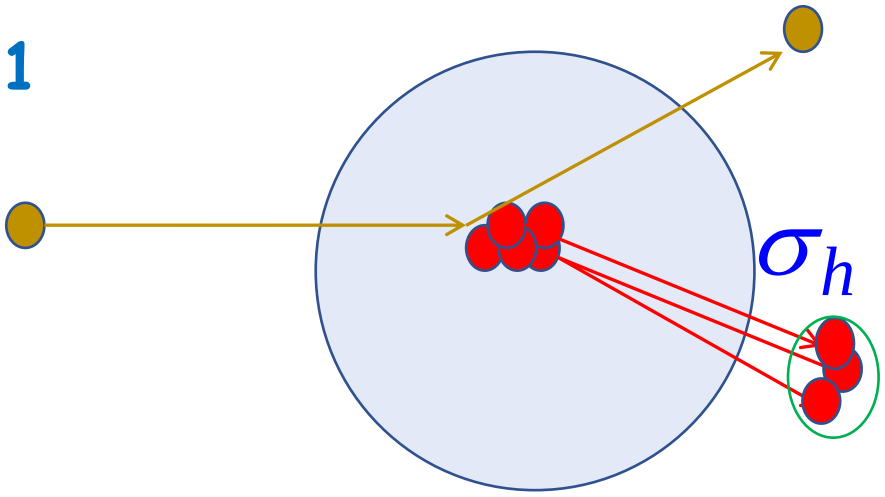
Flucton configuration



Flucton case

Knock out of a nuclear fragment

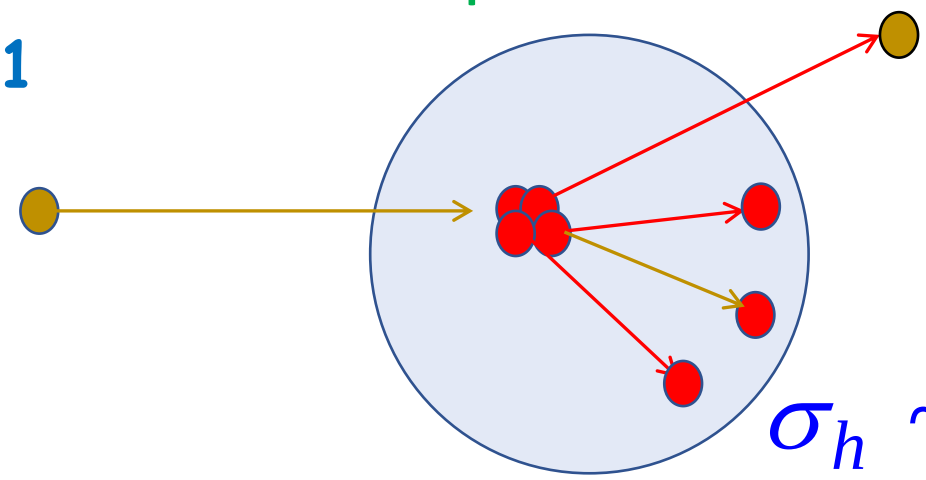
<B> > 1



$$\sigma_h \sim P_K \cdot \frac{d\sigma_{"el"}(K)}{dt}$$

Collision with hot flucton - small explosion

<B> < 1



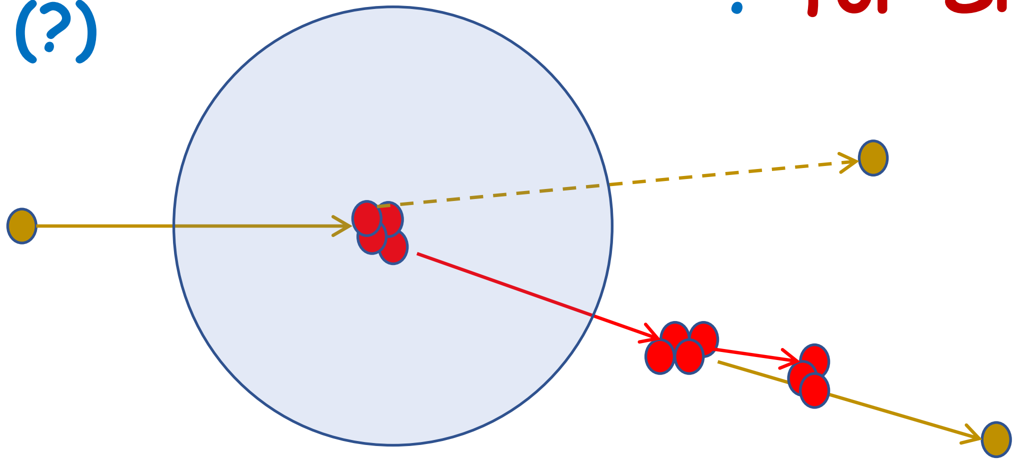
$$\sigma_h \sim P_K \cdot \frac{d\sigma_{inel}(K)}{dt}$$

Flucton case

Knock out of a flucton in an excited state

<B> > 1 (?)

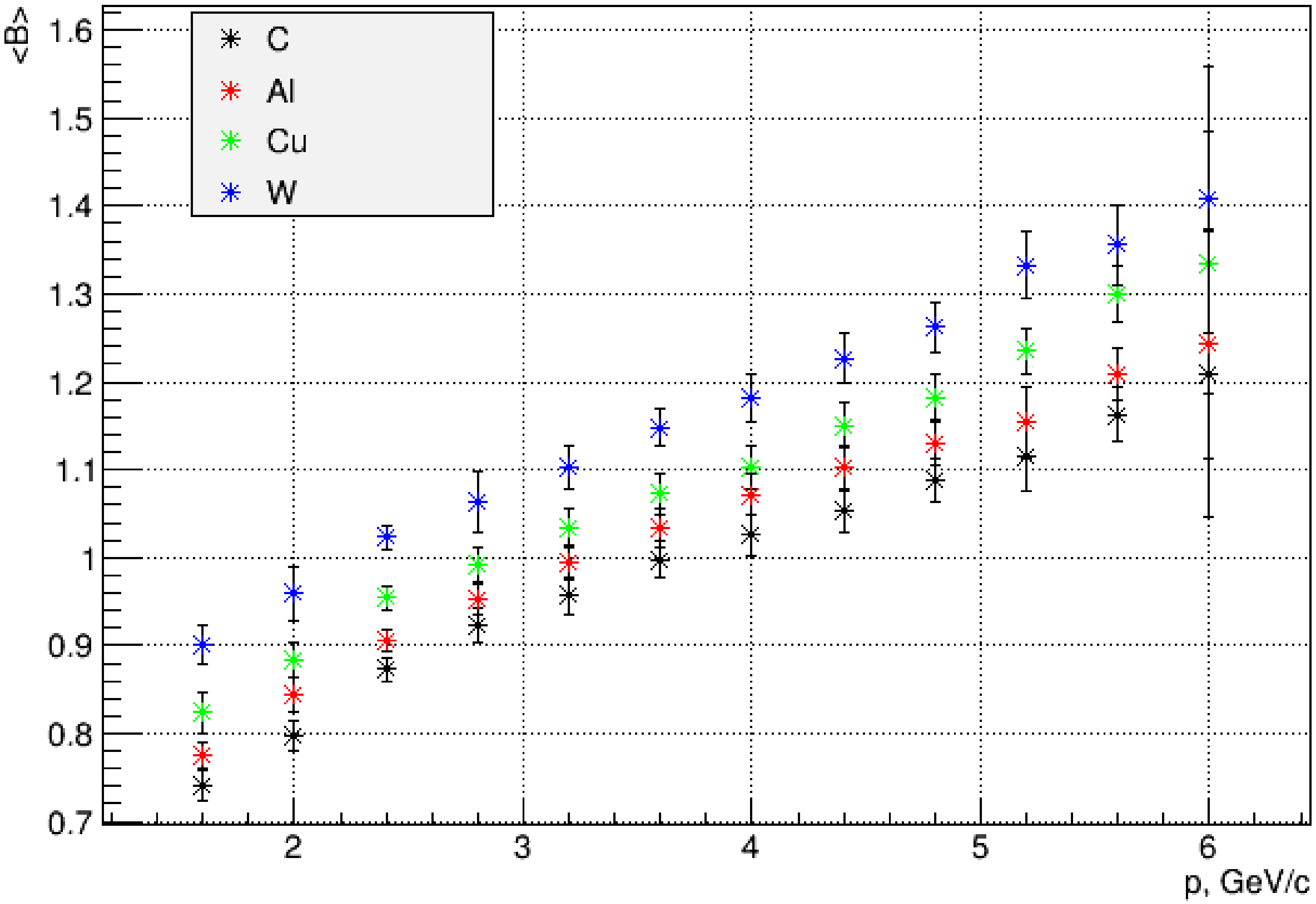
? for SPD and PANDA



SPIN data

N.N. Antonov et al., JETP Letters, Vol.101, No.10, pp.670-673(2015)

Average baryon number <B>



SPIN data

ISSN 0021-3640, JETP Letters, 2016, Vol. 104, No. 10, pp. 662–665. © Pleiades Publishing, Inc., 2016.
Original Russian Text © N.N. Antonov, A.A. Baldin, V.A. Viktorov, V.A. Gapienko, G.S. Gapienko, V.N. Gres', M.A. Ilyushin, V.A. Korotkov, A.I. Mysnik, A.F. Prudkoglyad, A.A. Semak, V.I. Terekhov, V.Ya. Uglekov, M.N. Ukhanov, B.V. Chuiko, S.S. Shimanskii, 2016, published in Pis'ma v Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, 2016, Vol. 104, No. 10, pp. 678–681.

FIELDS, PARTICLES, AND NUCLEI

Knockout of Deuterons and Tritons with Large Transverse Momenta in *pA* Collisions Involving 50-GeV Protons

N. N. Antonov[a], A. A. Baldin[b], V. A. Viktorov[a], V. A. Gapienko[a, *], G. S. Gapienko[a], V. N. Gres'[a], M. A. Ilyushin [a], V. A. Korotkov[a], A. I. Mysnik[a], A. F. Prudkoglyad[a], A. A. Semak[a], V. I. Terekhov[a], V. Ya. Uglekov[a], M. N. Ukhanov[a], B. V. Chuiko[a†], and S. S. Shimanskii[b]

$$\frac{E_d}{\sigma_{inel}}\frac{d^3\sigma_A}{dp_A^3} = B_A \times \left(\frac{E_p}{\sigma_{inel}}\frac{d^3\sigma_p}{dp_p^3}\right)^A$$

Mean values of the B_2 parameter

Target	C	Al	Cu	W
$B_2 \times 10^2$, GeV$^2/c^3$	1.41 ± 0.10	1.56 ± 0.08	1.51 ± 0.07	1.41 ± 0.06

D.I. Blokhintsev prediction 1957

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.

CsDBM

1. Cold - exists inside ordinary nuclear matter as a quantum component of the wave function (with some probability and life time).

2. superDense - several nucleons can be in a volume less than the nucleon volume. The mass will be several nucleon masses. The small size means that the multinucleon(multiquark) configuration seeing as point like objects in processes with high transfer energy.

3. Baryonic Matter – enhancement of baryonic states and suppression of sea and gluon degrees of freedom (mesons and antiparticles production).

HIGH p_T ISSUES at SPD, PANDA and J-PARC-HI

NN – interactions mainly

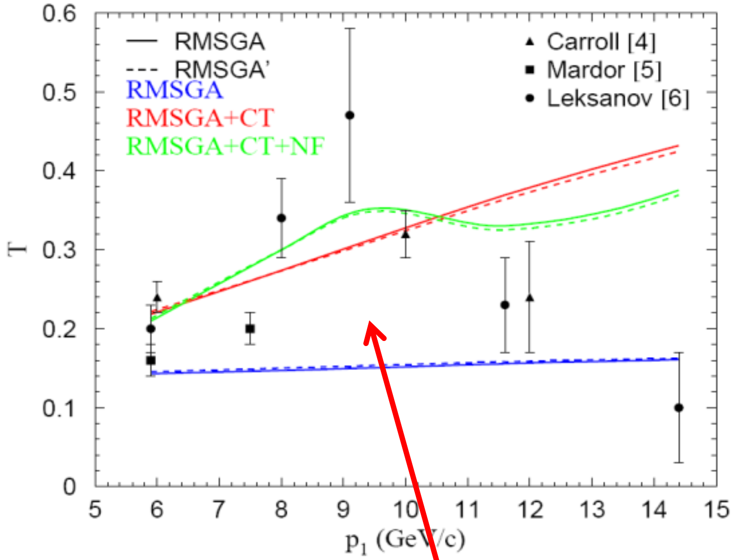
1. Flavor universality (pp- and nn-interactions).
2. Diquark properties.
3. Exotic states.
4. Nature of the spin effects.
5. FSI (with s,c-quarks participation).
6. ΛN - hypernuclei.
7. …

NA- and AA – interactions

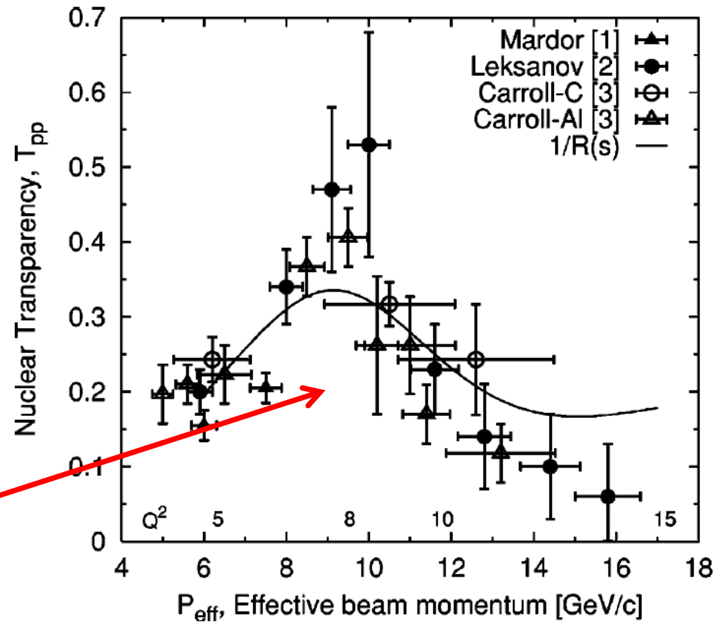
8. Nature of CsDBM and CT.
9. Subthreshold J/Ψ production.
10. The Deuteron spin structure.
11. np(nn) dilepton anomaly.
12. …

Thank you!

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



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



p_T ~ 2 GeV/c region

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 ~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].

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

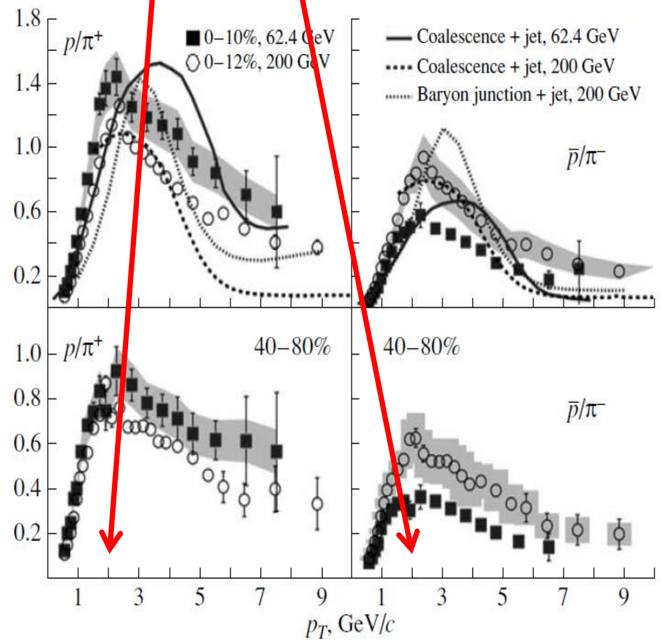


Fig. 3. [10] Ratio of the cross sections for the production of protons and charged pions as a function of the transverse momentum for various degrees of centrality and two beam energies of 62.4 and 200 GeV: (points) results of the STAR experiment and (curves) results of model calculations.

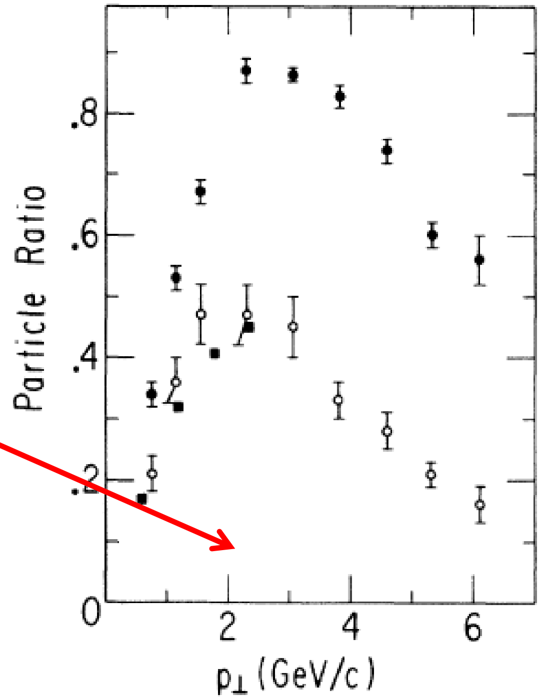
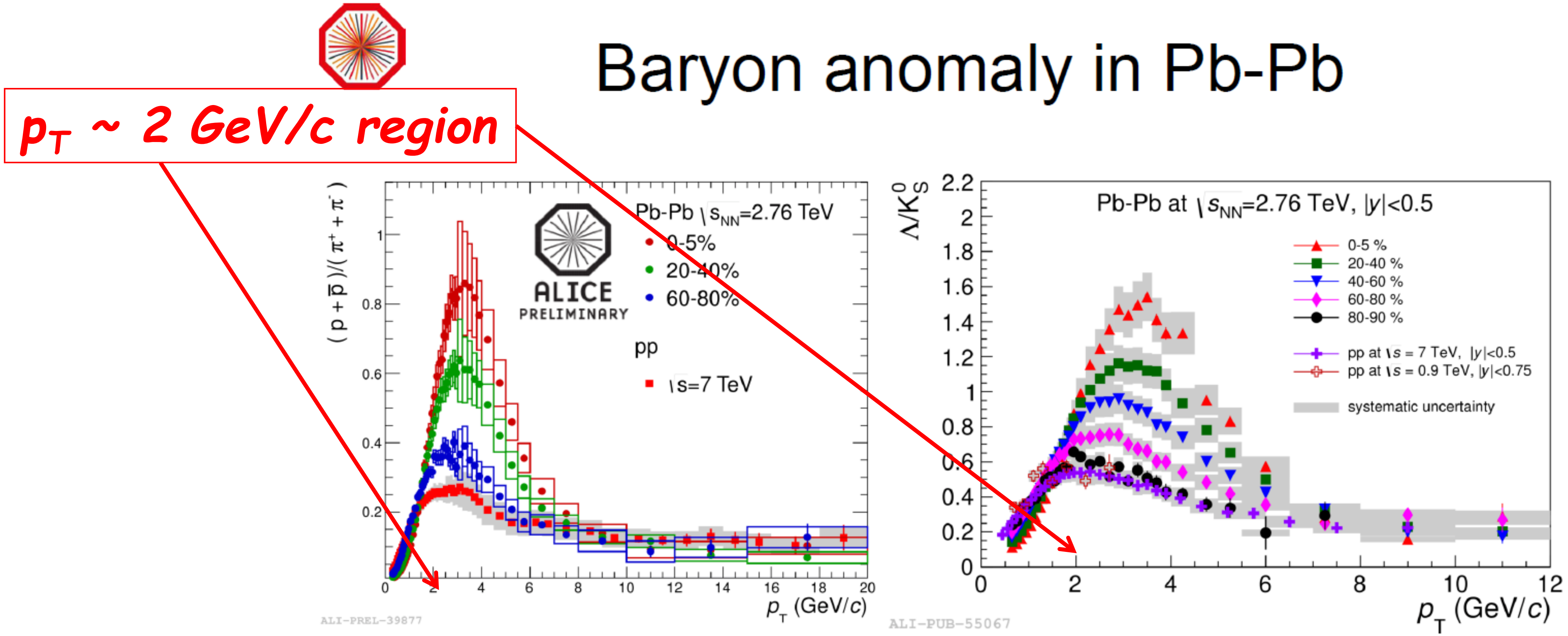


FIG. 20. Comparison of the cross-section ratio p/π^+ measured on tungsten at $\sqrt{s}=23.7$ GeV (closed circles), with that obtained by extrapolation to $A=1$ (open circles). Ratios obtained from the British-Scandinavian collaboration (Ref. 23) at $\sqrt{s}=23.4$ GeV are also plotted (closed squares).

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

Baryon anomaly in Pb-Pb



- Baryon to meson ratio increasing with centrality for p_T < 8 GeV/c.
  - Enhancement at moderate p_T is consistent with radial flow
  - May be explained by quark recombination from QGP (coalescence model)
- For p_T > 8 GeV/c no dependence on centrality and collision system
  - Consistent with fragmentation in vacuum

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.

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)

«ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА», 1980,
ТОМ 11, ВЫП. 3

УДК 539.171.1

РАССЕЯНИЕ ЧАСТИЦ ВЫСОКОЙ ЭНЕРГИИ КАК МЕТОД ИССЛЕДОВАНИЯ МАЛОНУКЛОННЫХ КОРРЕЛЯЦИЙ В ДЕЙТОНЕ И ЯДРАХ

М. И. Стрикман, Л. Л. Франкфурт

Ленинградский институт ядерной физики им. Б. П. Константинова, Ленинград

МАТЕРИАЛЫ XIII ЗИМНЕЙ ШКОЛЫ ЛИЯФ 1978

I41

КУМУЛЯТИВНЫЕ НУКЛОНЫ И КОРОТКОДЕЙСТВУЮЩИЕ КОРРЕЛЯЦИИ В ЯДРЕ

М.И.Стрикман и Л.Л.Франкфурт

малых расстояний в ядрах и о способе их описания представляет самостоятельный интерес. Цель обзора — показать, что отбор событий, содержащих кумулятивные частицы, увеличивает относительный вклад от конфигураций в волновой функции ядра, содержащих несколько нуклонов (два, три) на малых относительных расстояниях *. (Кумулятивными частицами мы, следуя [6], называем вторичные частицы, образующиеся в кинематической области, запрещенной для рассеяния на свободном нуклоне. Независимо от теоретической интерпретации этот термин удобен для обозначения указанной кинематической области.)

6. Балдин А. М.— Краткие сообщ. по физике, 1971, т. 1, с. 35.

Status of the pentaquark problem

- 1st relatively certain theoretical suggestion of mass ~1530 MeV and width < 15 MeV :

  Diakonov, Petrov, Polyakov, Z.Phys., A**359** (1997) 305.

- Experiment : about ten papers with positive evidences;

  about ten papers with negative results

  (some of them with higher statistics).

- Common opinion and PDG position (since edition of 2008) :

  Pentaquark is dead !

  (Note, at the same time, great enthusiasm in searches for tetraquarks !)

TABLE I. Proton-proton elastic scattering cross sections at 90° in the center-of-mass system.

$P_{c.m.}^2$ $(GeV/c)^2$	P_0 (GeV/c)	$(d\sigma/d\Omega)_{c.m.}$ $(\mu b/sr)$	$(d\sigma/dt)_{c.m.}$ $\mu b/(GeV/c)^2$	Error in $d\sigma/d\Omega$ & $d\sigma/dt$ %
1.946	5.0	8.51	13.74	2.9
1.993	5.1	7.90	12.45	3.3
2.039	5.2	7.09	10.93	3.1
2.086	5.3	6.49	9.77	3.6
2.132	5.4	5.53	8.15	3.1
2.178	5.5	4.90	7.07	3.4
2.223	5.6	4.47	6.32	3.1
2.270	5.7	3.72	5.15	3.3
2.316	5.8	3.37	4.57	3.3
2.363	5.9	2.74	3.64	3.5
2.409	6.0	2.44	3.18	3.1
2.456	6.1	2.19	2.80	3.7
2.503	6.2	1.83	2.30	3.7
2.595	6.4	1.50	1.82	3.7
2.686	6.6	1.07	1.25	4.7
2.779	6.8	0.796	0.900	4.7
2.873	7.0	0.645	0.706	4.1
2.965	7.2	0.515	0.546	4.0
3.059	7.4	0.386	0.396	4.8
3.151	7.6	0.305	0.304	5.4
3.247	7.8	0.253	0.245	4.5
3.338	8.0	0.217	0.204	4.5
3.386	8.1	0.169	0.157	3.9
3.434	8.2	0.172	0.157	4.4
3.480	8.3	0.154	0.139	3.8
3.527	8.4	0.153	0.136	4.6
3.618	8.6	0.127	0.110	4.6
3.713	8.8	0.103	0.0871	4.8
3.806	9.0	0.0809	0.0667	4.6
3.897	9.2	0.0780	0.0629	4.3
3.992	9.4	0.0676	0.0532	5.3
4.084	9.6	0.0589	0.0453	4.9
4.178	9.8	0.0536	0.0403	4.7
4.272	10.0	0.0468	0.0344	4.9
4.364	10.2	0.0441	0.0318	4.8
4.461	10.4	0.0386	0.0272	4.7
4.554	10.6	0.0356	0.0246	4.8
4.644	10.8	0.0303	0.0205	4.9
4.739	11.0	0.0284	0.0188	5.5
4.831	11.2	0.0255	0.0166	5.4
4.924	11.4	0.0202	0.0129	5.4
5.018	11.6	0.0190	0.0119	5.2
5.112	11.8	0.0153	0.00940	5.4
5.208	12.0	0.0143	0.00862	5.4
5.299	12.2	0.0118	0.00699	5.3
5.392	12.4	0.0116	0.00676	5.4
5.490	12.6	0.00953	0.00545	6.3
5.579	12.8	0.00867	0.00488	5.7
5.674	13.0	0.00739	0.00409	5.9
5.770	13.2	0.00722	0.00393	7.1
5.861	13.4	0.00525	0.00281	5.7

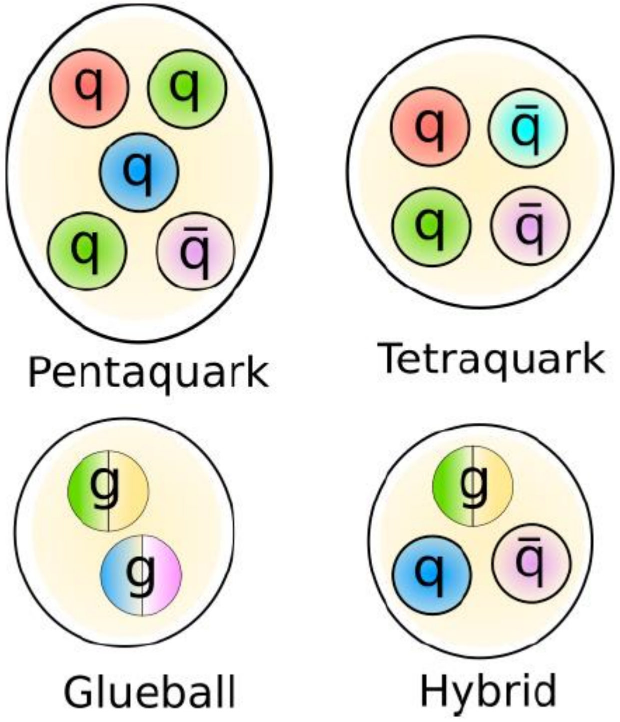
The rate for $L \sim 10^{30}\ cm^{-2}c^{-1}$:

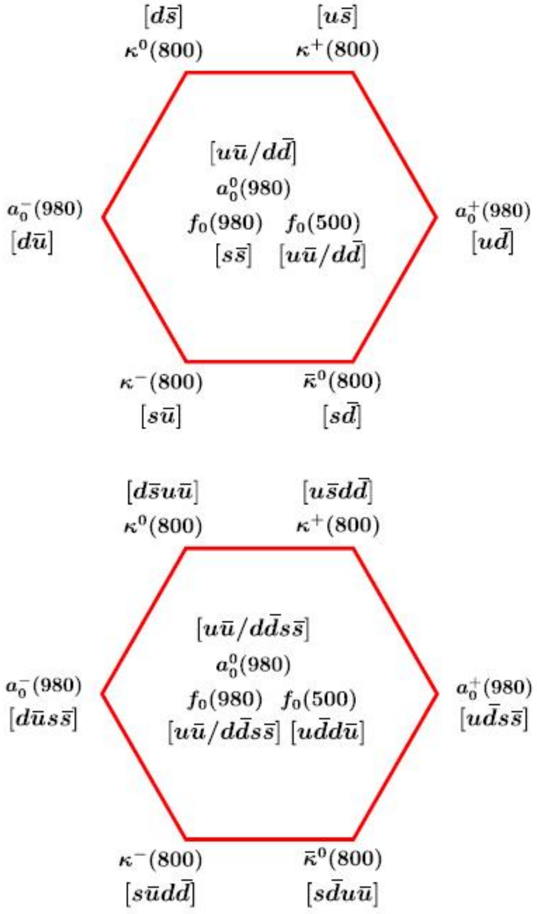
$\sim 0.2\ c^{-1}$ (at P_0 = 7.6 GeV/c)

$\sim 0.01\ c^{-1}$ (at P_0 = 10.4 GeV/c)

Tetraquarks in the light meson sector

Light meson sector: scalars!





PETERSBURG NUCLEAR PHYSICS INSTITUTE NAMED BY B.P. KONSTANTINOV
Petersburg Nuclear Physics Institute
OF NATIONAL RESEARCH CENTRE «KURCHATOV INSTITUTE»

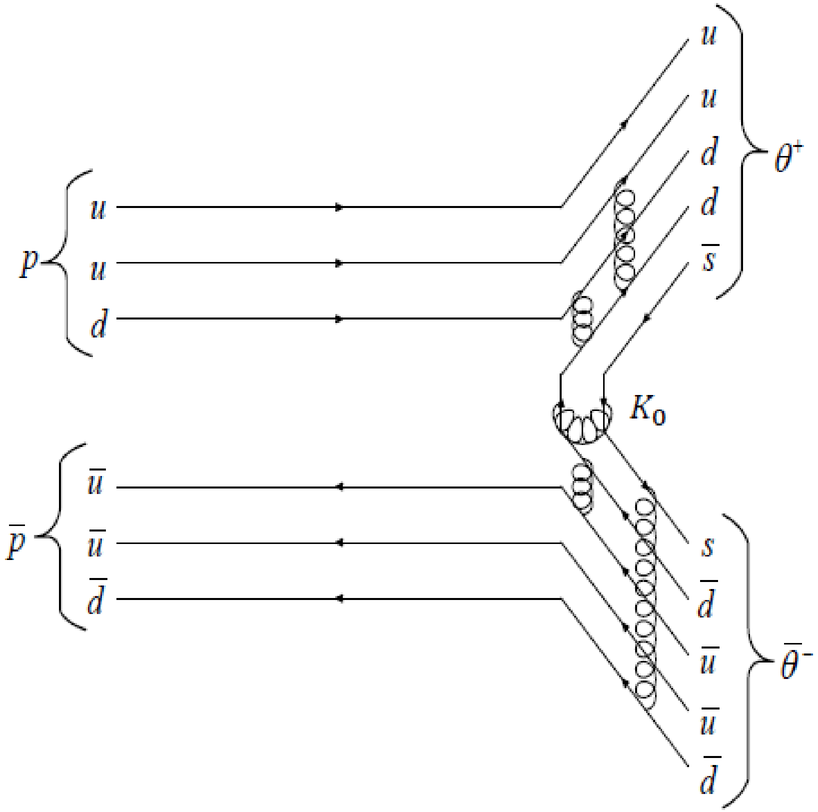
Study of feasibility to detect pentaquark $\theta^{+}(\bar{\theta}^{-})$ in PANDA

S.Belostotski, S.Manaenkov, V.Petrov, D.Veretennikov

PANDA collaboration meeting 19/3,
November 4-8, 2019, GSI

Exclusive $\theta^{+}(\bar{\theta}^{-})$ production in p anti-p collision

Pentaquark production by K-meson exchange



Differential cross-section
(V.Petrov, S.Manaenkov)

$$\frac{d\sigma}{dt} = \frac{g^4[(M_\theta - m_N)^2 - t]^2}{16\pi s(s - 4m_N^2)(M_K^2 - t)^2}$$

m_N is nucleon mass
M_K is K^0 mass
M_θ is pentaquark mass
s, *t* are the Mandelstam variables

Total cross-section

$$\sigma_{tot} = \frac{g^4}{16\pi s(s-4m_N^2)}\Big\{[(M_\theta - m_N)^2 - M_K^2]^2 \Big[\frac{1}{M_K^2 - t_{max}} -$$

θ^+ total width

$$\Gamma_{tot} = \frac{g^2 P_0^3}{\pi[(M_\theta + m_N)^2 - M_K^2]}$$

P_0 is momentum of K^0 in θ^+ rest system