"Cold dense baryonic matter (multiquark states) at PANDA"

S.S. Shimanskiy (JINR, LHEP)

PLAN

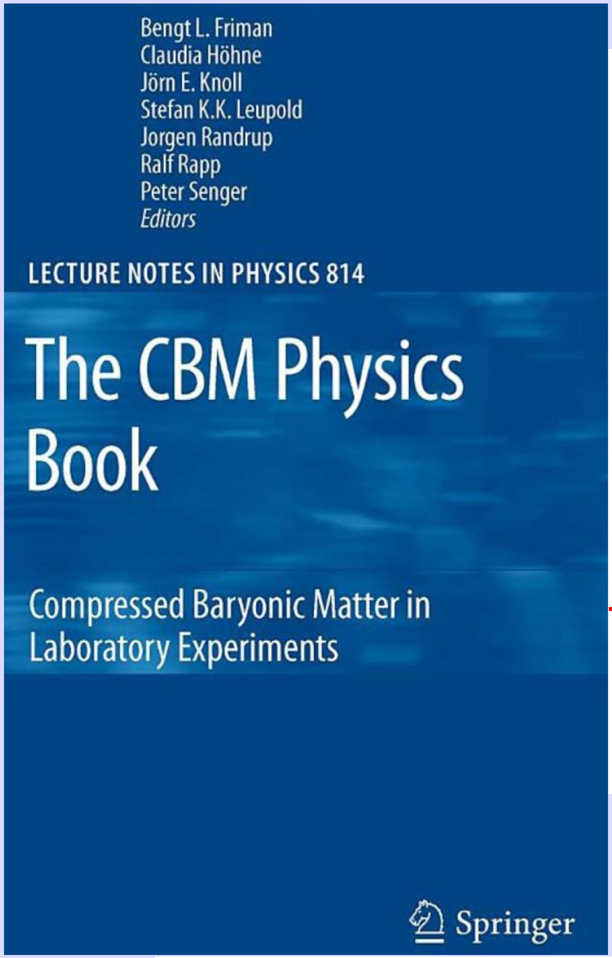
1. Cold Dense Baryonic Matter (CDBM) is reality or fiction?

2. The discovery and study of CDBM.

3. High p_T probes and SPIN data.

4. Unique PANDA features.

CBM at FAIR



The theoretical foundation of the Strong Force, Quantum Chromodynamics (QCD), is well established, as part of the Standard Model of Elementary Particles, with quarks and gluons as the fundamental degrees of freedom. However, key phenomena in strong interactions have evaded a profound understanding to date, most notably the confinement of quarks and gluons into hadrons and the generation of mass. These phenomena are believed to be intimately related to phase changes in strongly interacting matter, which is one of the main motivations for the research addressed in the present book. In nature, hot deconfined matter (the so-called Quark-Gluon Plasma) filled the early universe, just a few microseconds after the Big Bang, while present-day compact stars may contain cold and baryon-rich quark matter in their interior. The prospect of creating and studying this fundamental form of matter in modern-day laboratory experiments is truly fascinating. It enables a close interplay of experimental data and theoretical interpretation which is pivotal for scientific progress in this field. Nearly forty years of nuclear collision experiments, at laboratories across the world, have led to spectacular new insights, including the discovery of new forms and novel properties of matter.

Some of these developments have identified the regime of high baryon densities as a particularly interesting one. This is the main motivation for the proposed Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt. Closely related

What will be investigate at CBM?

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
2008-005

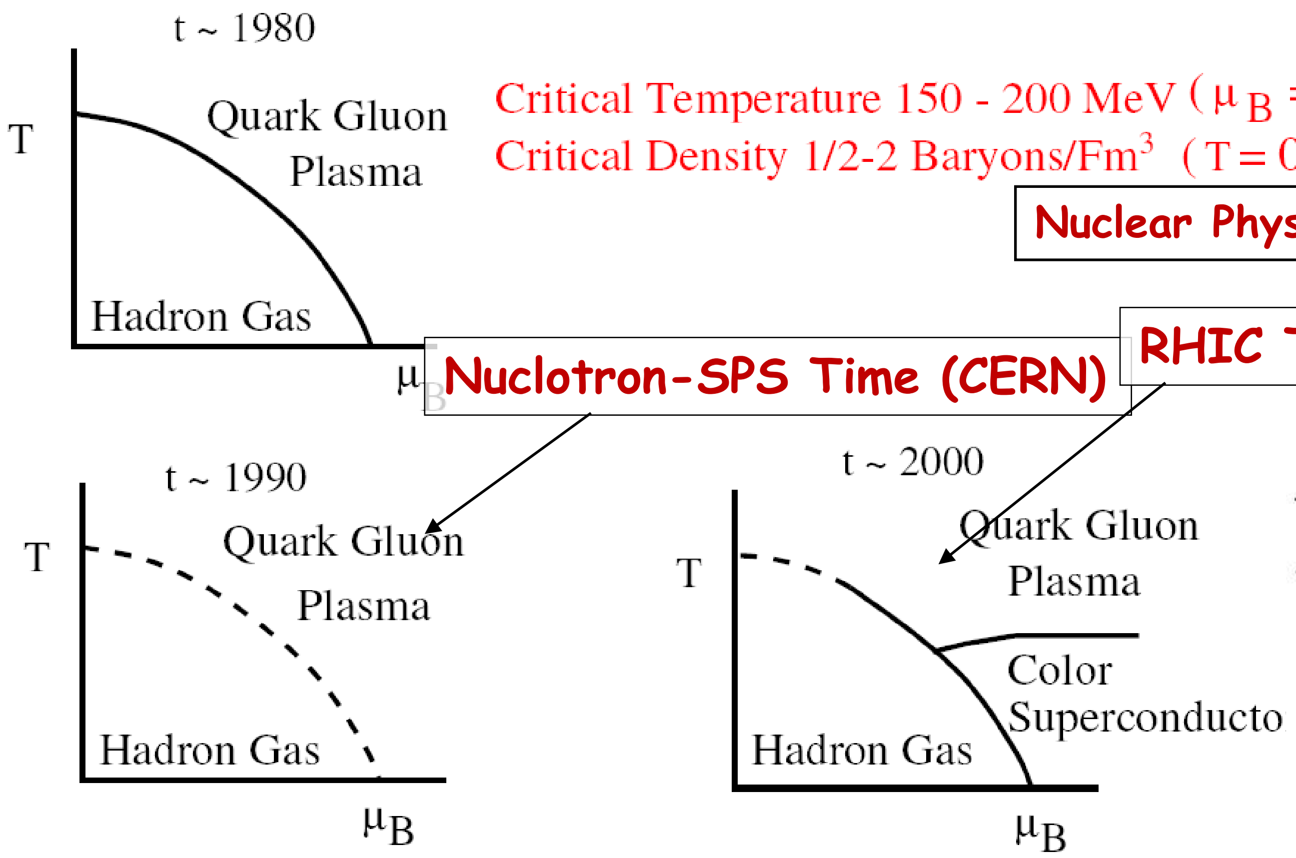
The Evolving QCD Phase Transition

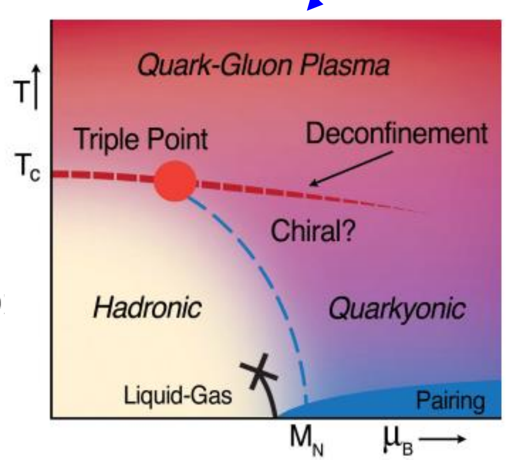
Critical Temperature 150 - 200 MeV ($\mu_B = 0$)
Critical Density 1/2-2 Baryons/Fm^3 ($T = 0$)

Nuclear Physics A 837 (2010) 65–86

RHIC Time(BNL)

Nuclotron-SPS Time (CERN)



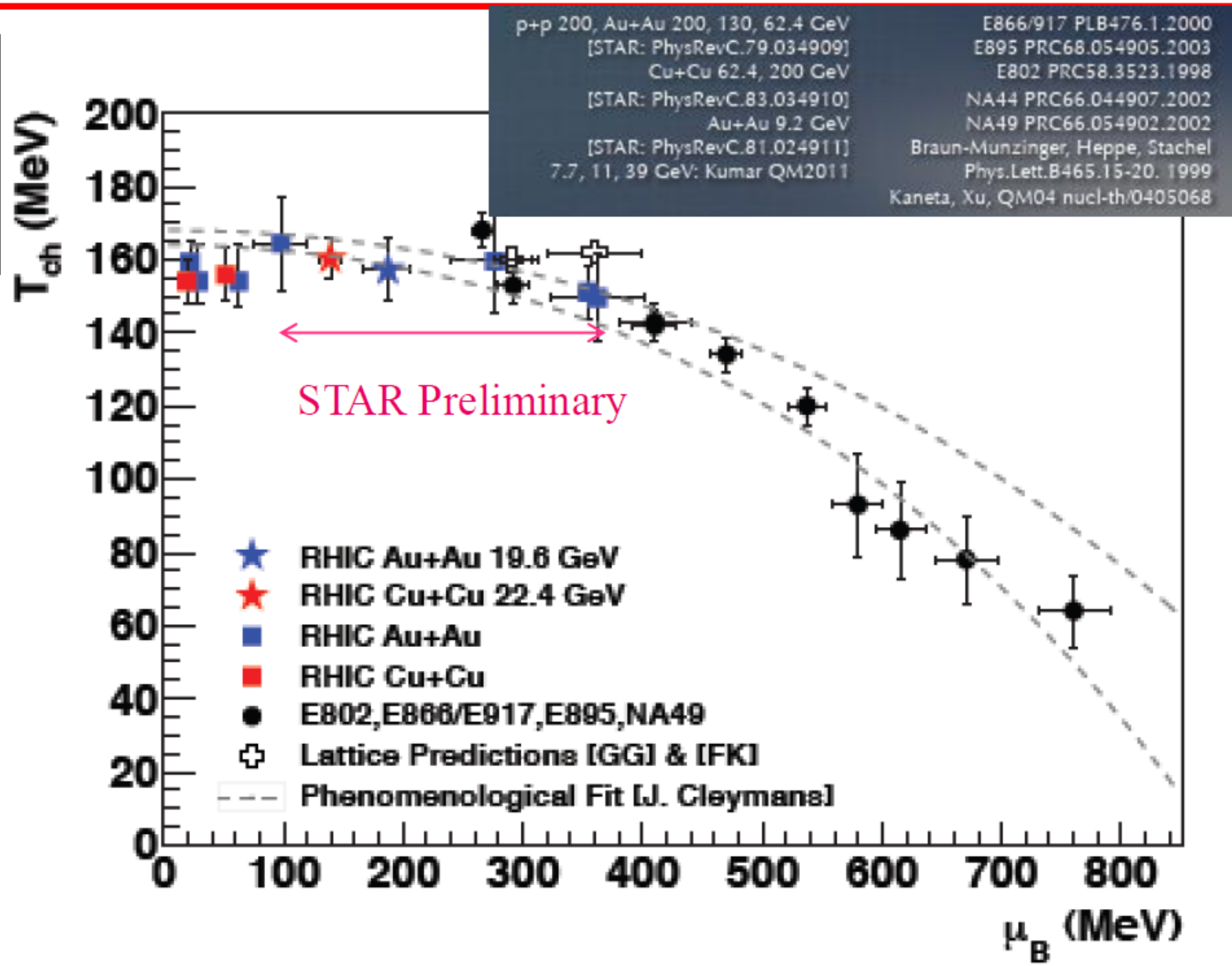


Where are We on the Phase Diagram

STAR

$$\frac{d^6N}{dx^3dp^3} = g \ln\left(\frac{1}{e^{\frac{E-\mu}{T}} \pm 1}\right)$$

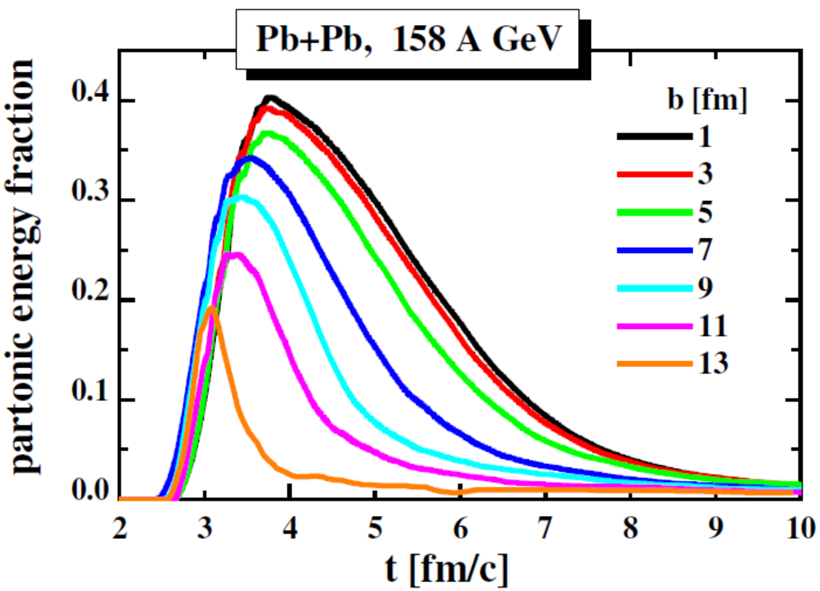
Using the particle ratios from the π, K, and p and a thermal model, we can determine our location on the phase diagram

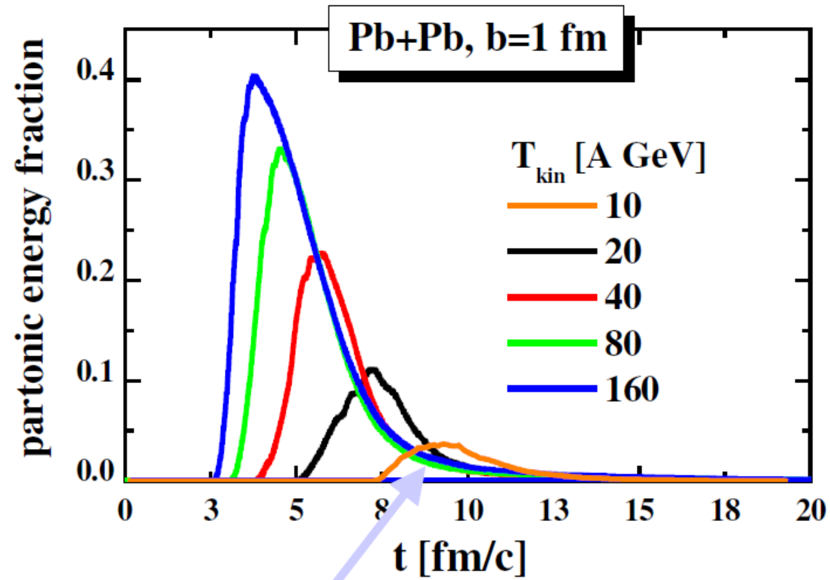


O. Mall SQM2011

Partonic phase at SPS/FAIR/NICA energies

partonic energy fraction vs centrality and energy





Dramatic decrease of partonic phase with decreasing energy and centrality

Cassing & Bratkovskaya, NPA 831 (2009) 215

CDBM

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

2. Dense - 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.

CDBM - continuation

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

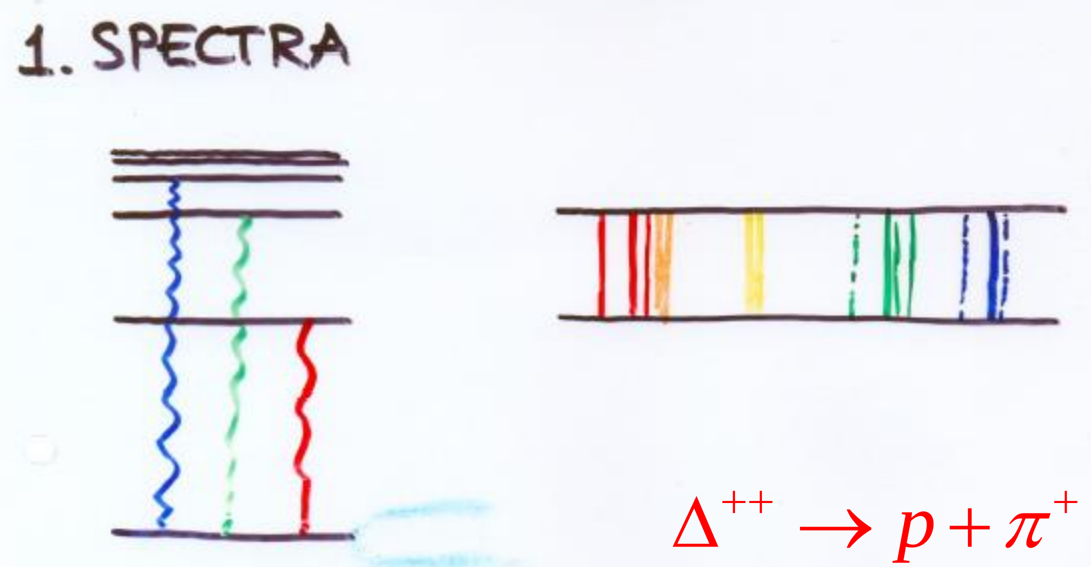
The discovery and study of CDBM.

F. Close

Structure of Matter

Two ways that structure is revealed:

$$A^{*} \rightarrow A + \gamma$$



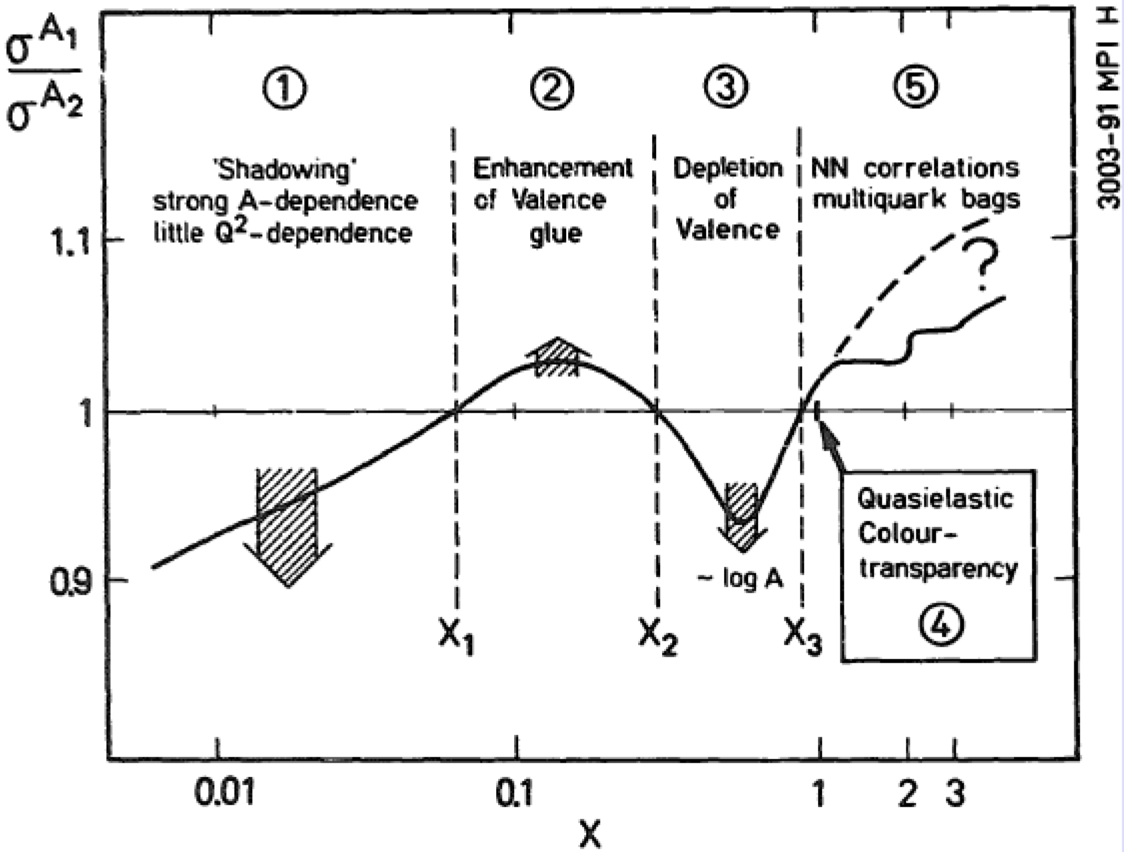
$$\Delta^{++} \rightarrow p + \pi^{+}$$

True from atoms to particles…..

DIS with Leptons

Nuclear Physics A532 (1991) 3c–14c

K.Rith



Region 5: $x_3 < x < x_A$

For a nucleus with atomic mass A the quark distributions can in principle extend to $x_A = A$. $R^A(x)$ is bigger than one. Its behaviour is strongly influenced by Fermi-motion, final state interactions, nucleon-nucleon correlations, or the formation of multiquark clusters. Experimentally this region is essentially unexplored.

PHYSICAL REVIEW C VOLUME 45, NUMBER 4 APRIL 1992

Nuclear structure functions at $x > 1$

B. W. Filippone, R. D. McKeown, R. G. Milner,* and D. H. Potterveld†
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Institute of Nuclear and Particle Physics and Department of Physics, University of Virginia, Charlottesville, Virginia 22901

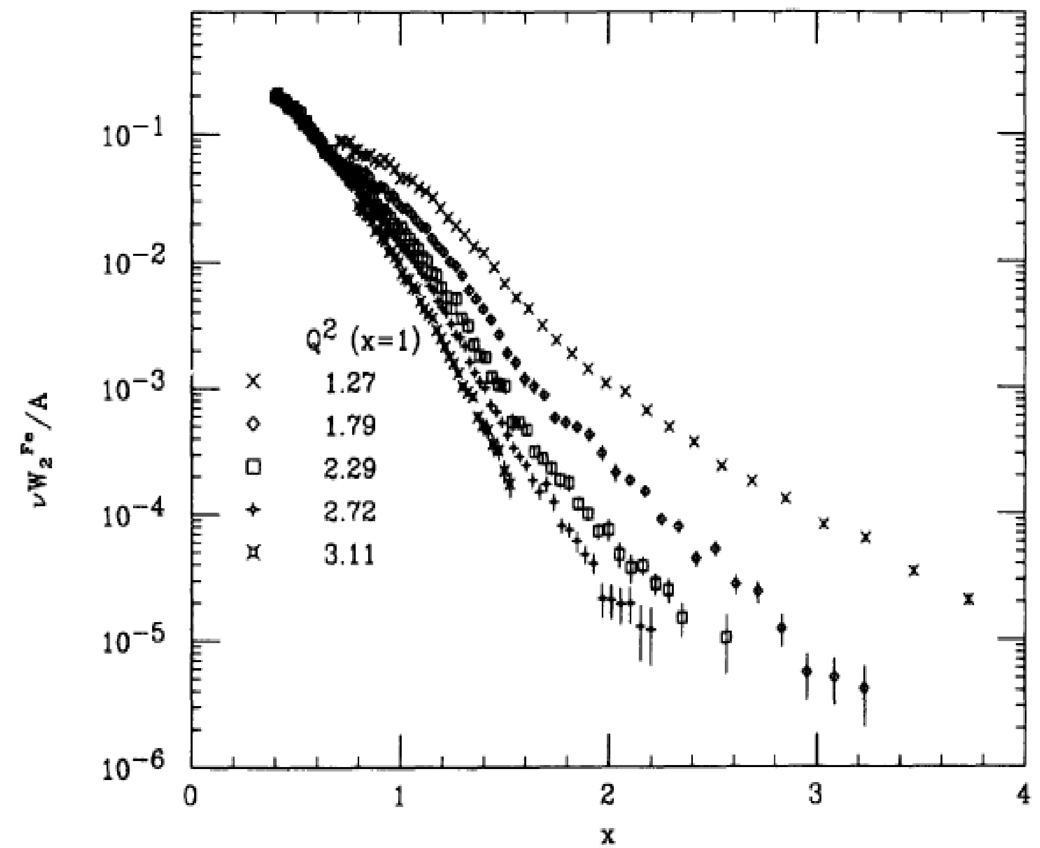
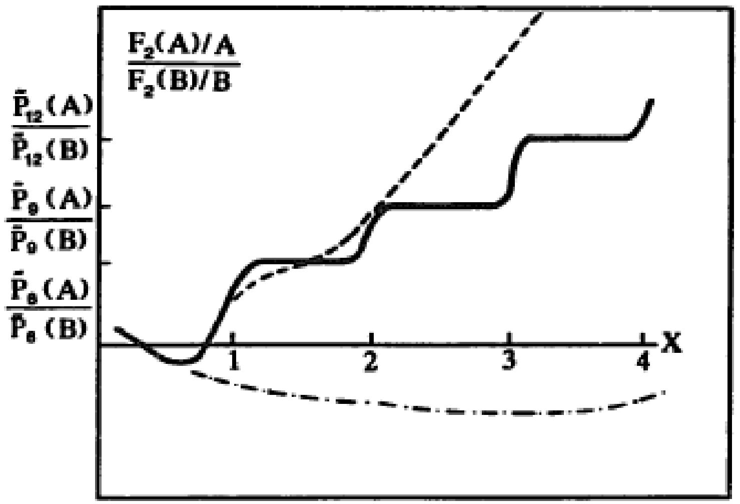


FIG. 1. Measured structure function per nucleon for Fe vs x. The Q^2 value at $x = 1$ is also listed for the different kinematics.



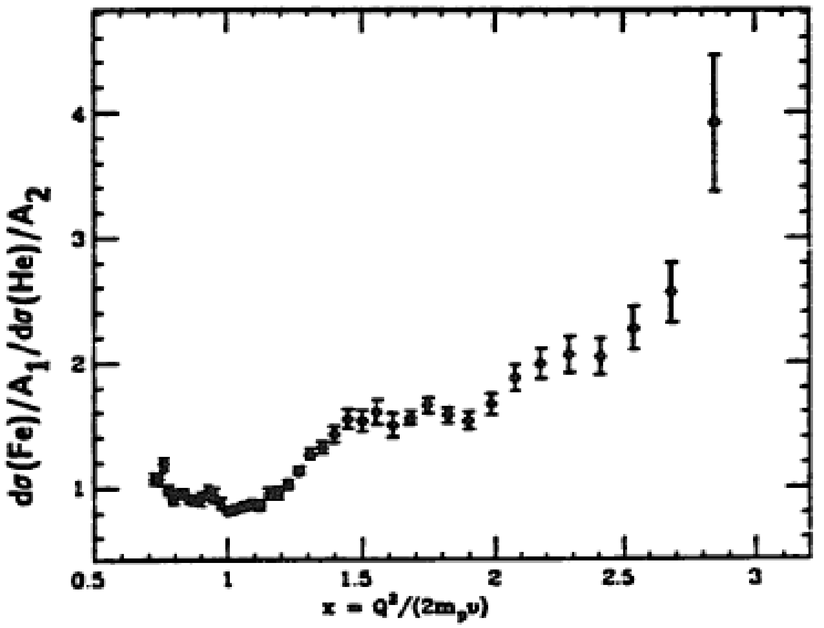


Figure 5. Theoretical predictions for nuclear structure functions at $x > 1$

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

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

N.P. Zotov, V.A. Saleev, V.A. Tsarev (Lebedev Inst.)
Published in JETP Lett. 40 (1984) 965-968, Pisma Zh.Eksp.Teor.Fiz. 40 (1984) 200-203

Z. Phys. C 63, 29–36 (1994)

ZEITSCHRIFT
FÜR PHYSIK C

Nuclear structure functions in carbon near $x = 1$

BCDMS Collaboration

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Received: 1 March 1994

Abstract. Data from deep inelastic scattering of 200 GeV muons on a carbon target with squared four-momentum transfer $52\,\mathrm{GeV}^2 \leq Q^2 \leq 200\,\mathrm{GeV}^2$ 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 $s = 16.5 \pm 0.6$.

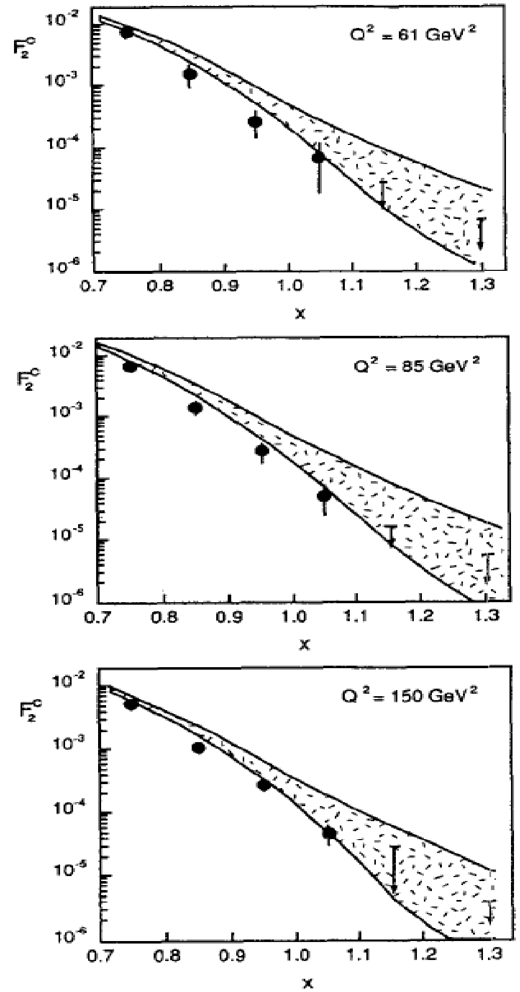

Fig. 7. The nuclear structure function $F_2^C(x)$ as a function of x, at three different values of Q^2. The hatched regions show the range of predictions of [26]

Phys.Rev.Lett. 96 (2006) 082501

Measurement of 2- and 3-Nucleon Short Range Correlation Probabilities in Nuclei

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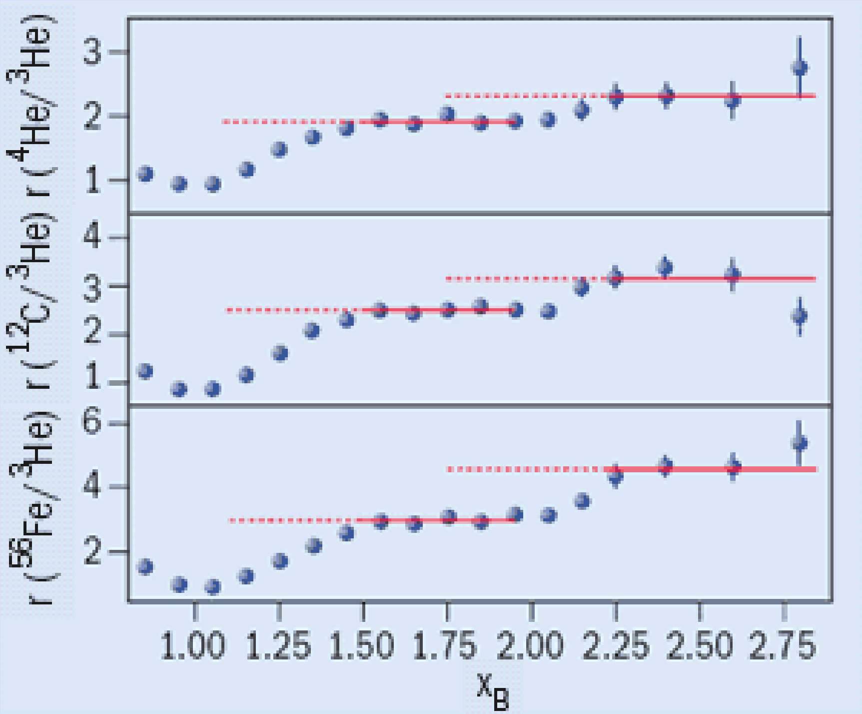
$$r(A, {}^3\mathrm{He}) = \frac{A(2\sigma_{ep} + \sigma_{en})}{3(Z\sigma_{ep} + N\sigma_{en})} \frac{3\mathcal{Y}(A)}{A\mathcal{Y}({}^3\mathrm{He})} C^A_{\mathrm{rad}}, \qquad (2)$$

where Z and N are the number of protons and neutrons in nucleus A, σ_{eN} is the electron-nucleon cross section, $\mathcal{Y}$ is the normalized yield in a given (Q^2, x_B) bin [30] and C^A_{rad} is the ratio of the radiative correction factors for A and ^{3}He ($C^A_{\mathrm{rad}} = 0.95$ and 0.92 for ^{12}C and ^{56}Fe respectively). In our Q^2 range, the elementary cross section correction factor $\frac{A(2\sigma_{ep}+\sigma_{en})}{3(Z\sigma_{ep}+N\sigma_{en})}$ is 1.14 ± 0.02 for C and ^{4}He and 1.18 ± 0.02 for ^{56}Fe. Fig. 1 shows the resulting ratios integrated over $1.4 < Q^2 < 2.6$ GeV^2.



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

$a_{2N}(^{12}C) \approx 20 \pm 0.2 \pm 4.1\ \%$ →

$a_{pp}(^{12}C) \approx 4 \pm 2\ \%$

$a_{pn}(^{12}C) \approx 12 \pm 4\ \%$

$a_{nn}(^{12}C) \approx 4 \pm 2\ \%$

SPECTRA

Volume 67B, number 1 PHYSICS LETTERS 14 March 1977

ТЕОРИЯ

LARGE MOMENTUM PION PRODUCTION IN PROTON NUCLEUS COLLISIONS AND THE IDEA OF "FLUCTUONS" IN NUCLEI

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and

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Joint Institute for Nuclear Research, Dubna, USSR

Received 27 January 1977

It is shown that in proton-nucleus collisions, the production of pions with large momenta can be explained by the assumption of the existence of nuclear density fluctuations ("fluctuons") at short distances of the nucleon core radius order, with the mass of several nucleons.

The purpose of this note is to realize the idea [4] that the cumulative effect is connected largely with a suggestion on the existence in nuclei of the so-called fluctuons. Earlier fluctuons were proposed [7] in order to understand the nature of the "deuteron peak" in the pA-scattering cross section at large momentum transfers [8] and also to interpret the pd-scattering cross section [9]. Compressional fluctuations of mass $M_k = km_p$ of nucleons in the small volume $V_\xi = \frac{4}{3}\pi r_\xi^3$ where r_ξ is the fluctuon radius were assumed.

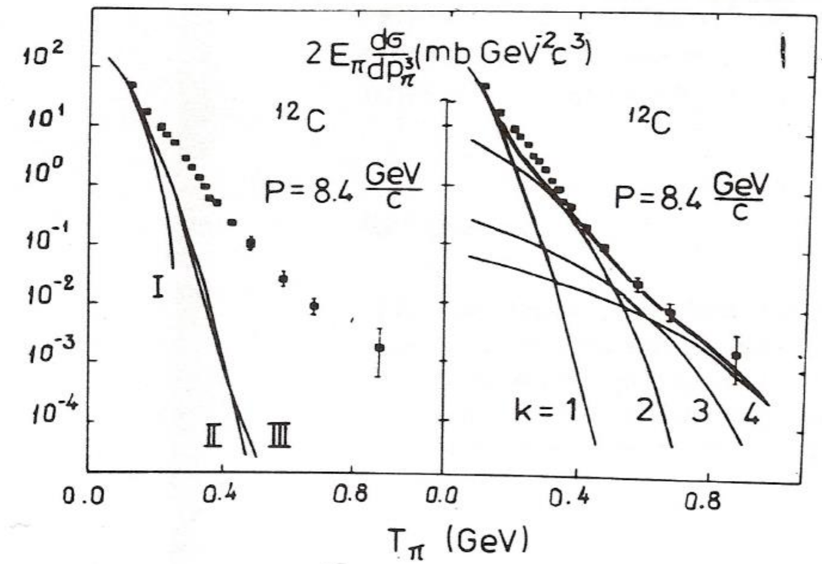


Fig. 1. (a) Calculations of the invariant pion production cross section for ^{12}C: I – for the free proton target; II – with fermi motion; III – the relativization effect. (b) The contributions of separate fluctuons with mass $M_k = km_p$ where k is the order of cumulativity.

Fluctons Probability inside nuclei

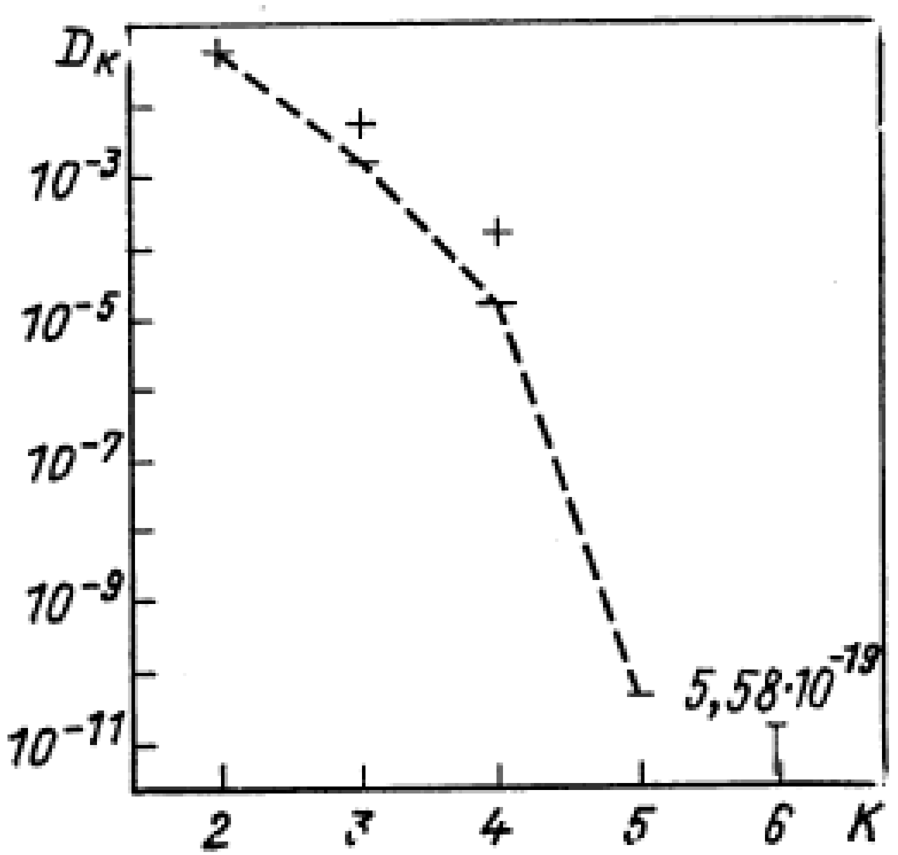


Рис. 19. Вероятность существования флуктонов с k нуклонами в ядрах

A - dependence (1974-…)

$$\varepsilon \frac{d\sigma}{dp}(p+A\to\pi) \sim \begin{cases} A - heavy\_nuclei \\ A^{n>1} - light\_nuclei \end{cases}$$

$$\varepsilon \frac{d\sigma}{dp}(p+A\to B) \sim \begin{cases} A^{5|/3} - for\_d \\ A^{2} - for\_t \end{cases}$$

The same time Cronin team at FNAL have seen about the same A-dependence for pA(for 200, 300, 400 GeV protons) high p_T Particle production

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

A.M.Baldin et al., Yad.Fiz., 20, 1975, p.1201

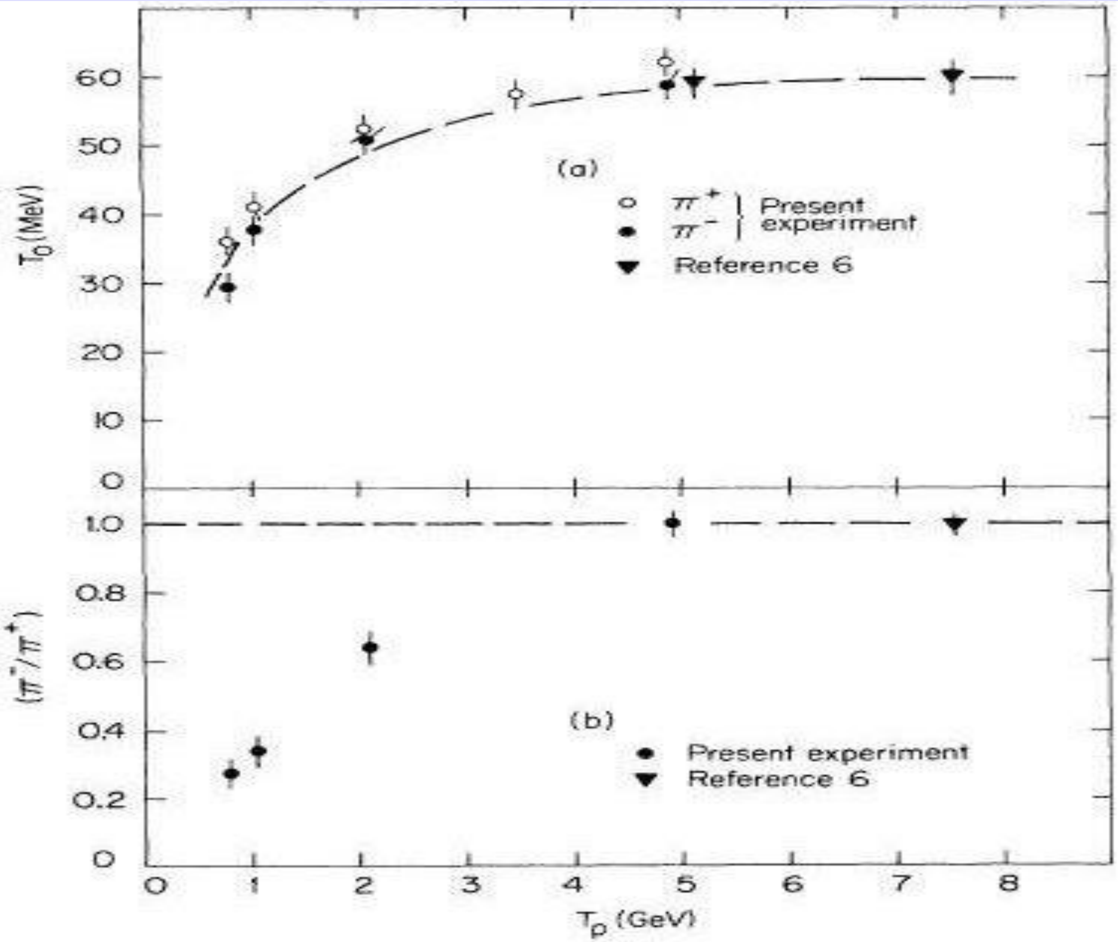
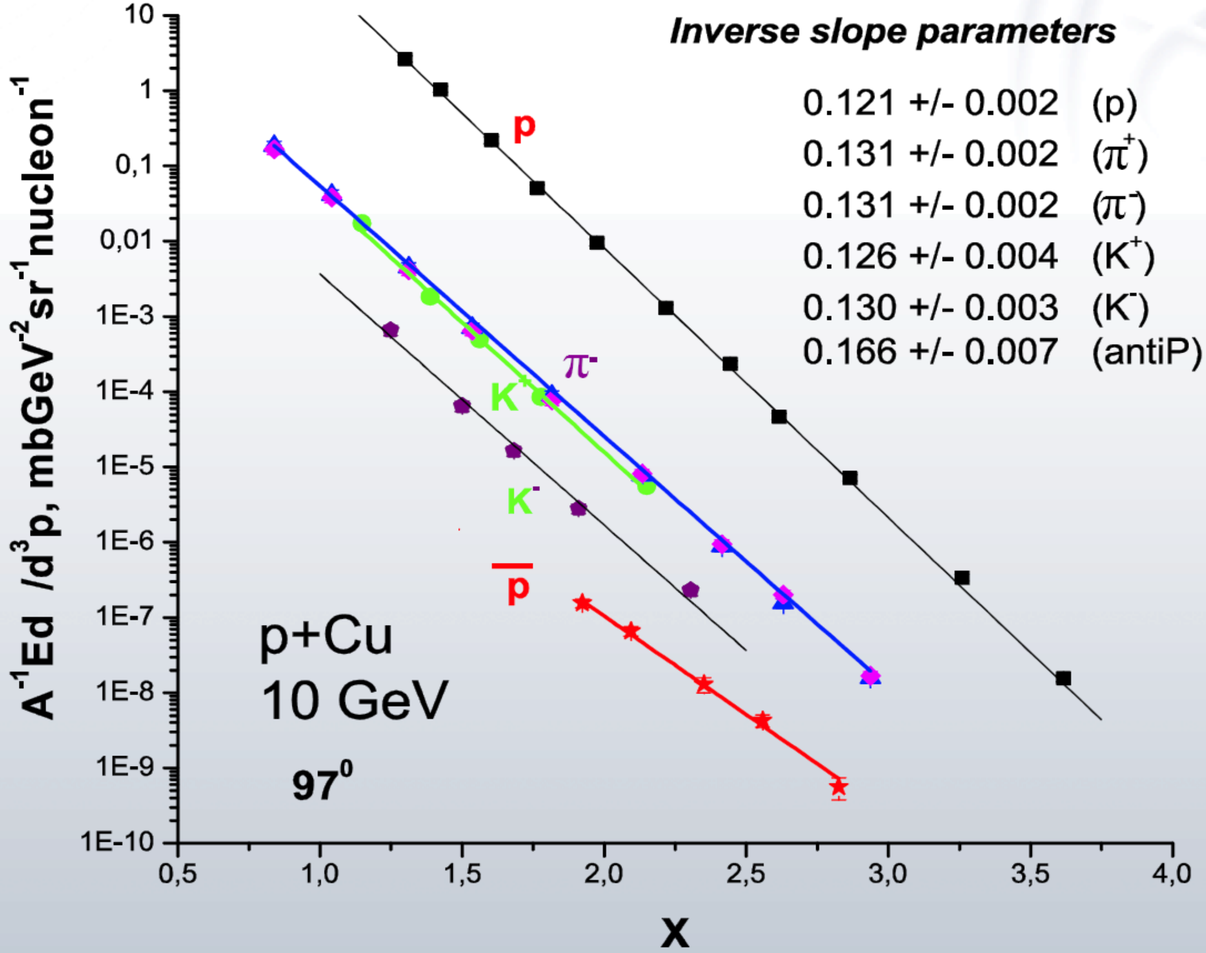


FIG. 1. Energy dependence of (a) T_0 parameter for pions, and (b) the π^-/π^+ ratio at 180° obtained by integrating each spectra up to 100 MeV for p-Cu collisions from 0.8 to 4.89 GeV. The dashed curve in both cases refers to the predictions of the "effective-target" model (Refs. 3 and 4).



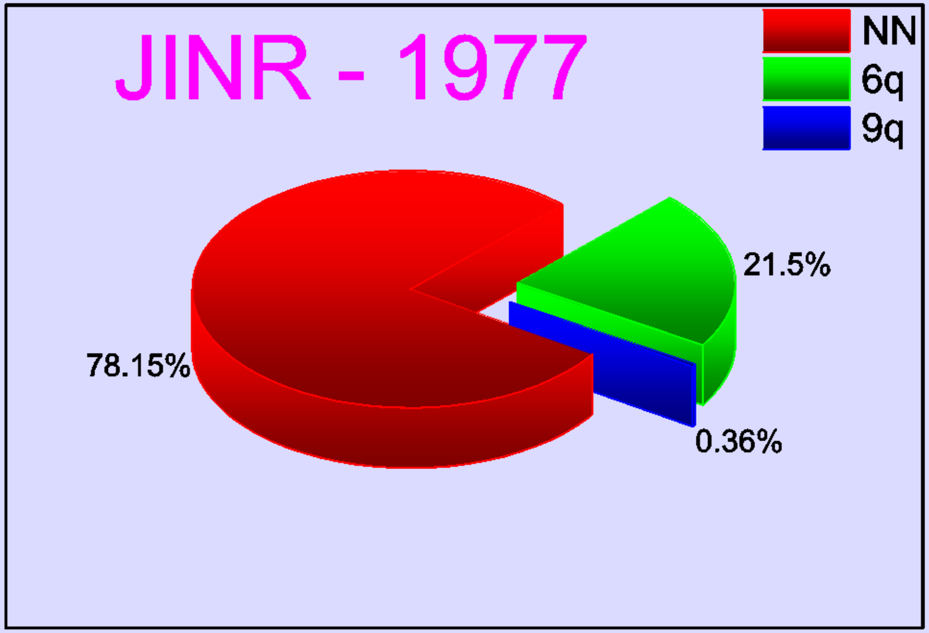
FAS @ ITEP (Boyarinov et.al Yad.Fiz 57 (1994) 1452)

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

^{12}C - structure

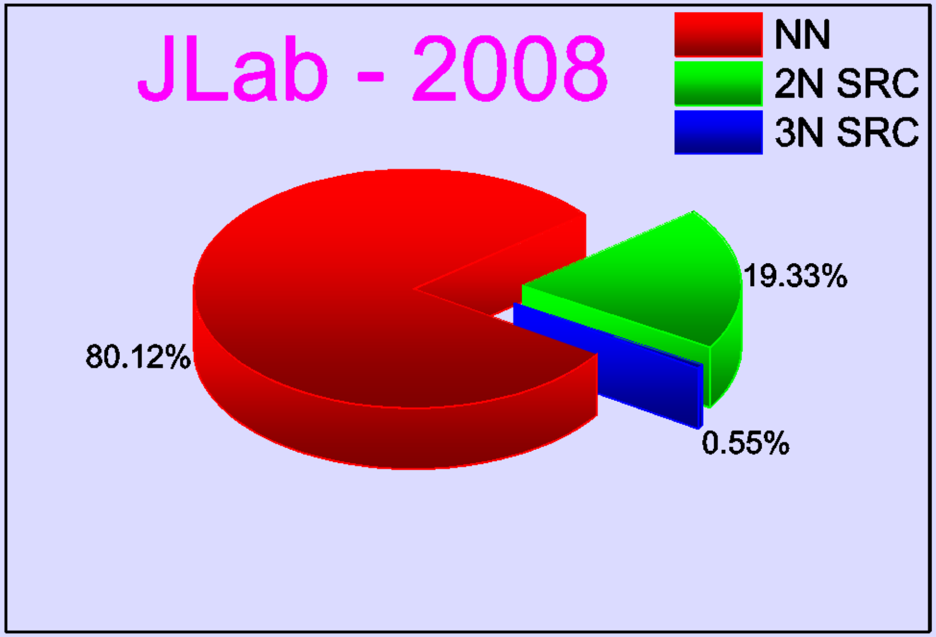
RNP - program at JINR

V.V.B., V.K.Lukyanov, A.I.Titov, PLB, 67, 46(1977)



eA - program at JLab

R.Subedi et al., Science 320 (2008) 1476-1478
e-Print: arXiv:0908.1514 [nucl-ex]



Correlation Measurements

Why need high p_T probes?

PHYSICAL REVIEW C VOLUME 51, NUMBER 2 FEBRUARY 1995

Probing short-range nucleon correlations in high-energy hard quasielastic *pd* reactions

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M. Strikman

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(Received 4 May 1994)

The main new result of this paper is the calculation of the initial and final state interaction in a hard exclusive proton-deuteron reaction. We find that for spectator momenta ≤ 350 MeV/c and $p_t \sim 0$ the effect of initial and final state interactions can be accounted for by rescaling the cross section calculated within the plane-wave impulse approximation. We show that the strong dependence of the amplitude for NN hard scattering on the collision energy and the exclusive nature of the quasielastic large-angle pd scattering can be used to magnify the effects of short-range nucleon correlations. The feasibility to investigate in this kinematical region the role of relativistic effects in the deuteron wave function is demonstrated by comparing the predictions of different relativistic approaches. It is demonstrated also that in these kinematics the final and initial state interactions reduce sensitivity of the cross section to uncertainties in the high-momentum component of the deuteron wave function. We also find that for $p_z \sim 0$ and 150 MeV/c $\geq p_t \geq$ 50 MeV/c initial and final state interaction strongly reduce the cross section while relativistic effects are very small. This kinematic is optimal for color-transparency studies. Binding effects due to short-range correlations in the deuteron are discussed as well.

PACS number(s): 13.75.Cs, 25.10.+s, 25.40.Ep

E850/EVA (BNL)

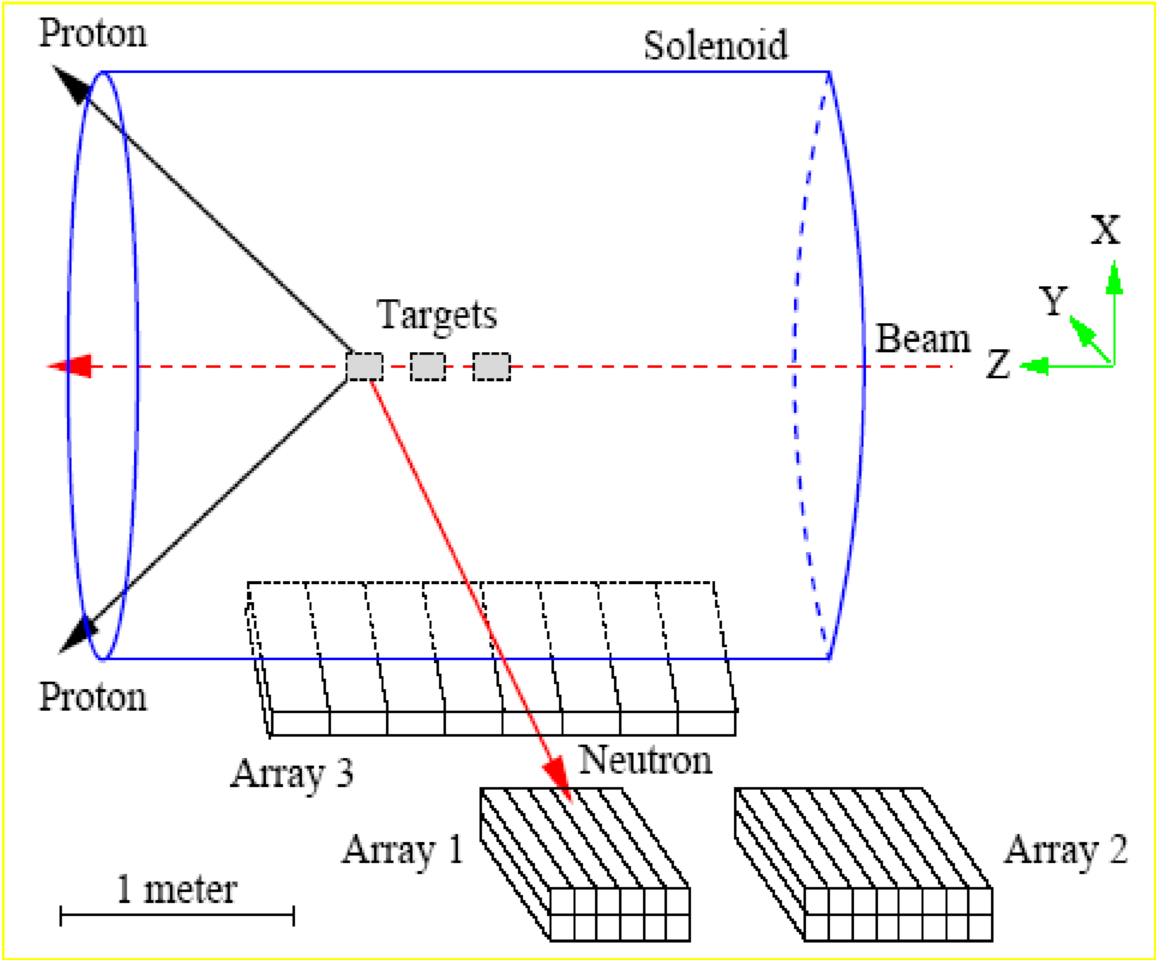

Figure I.3: A schematic view of the EVA solenoid and the neutron counters in the 1998 measurement.

VOLUME 90, NUMBER 4 PHYSICAL REVIEW LETTERS week ending 31 JANUARY 2003

n-p Short-Range Correlations from $(p, 2p + n)$ Measurements

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

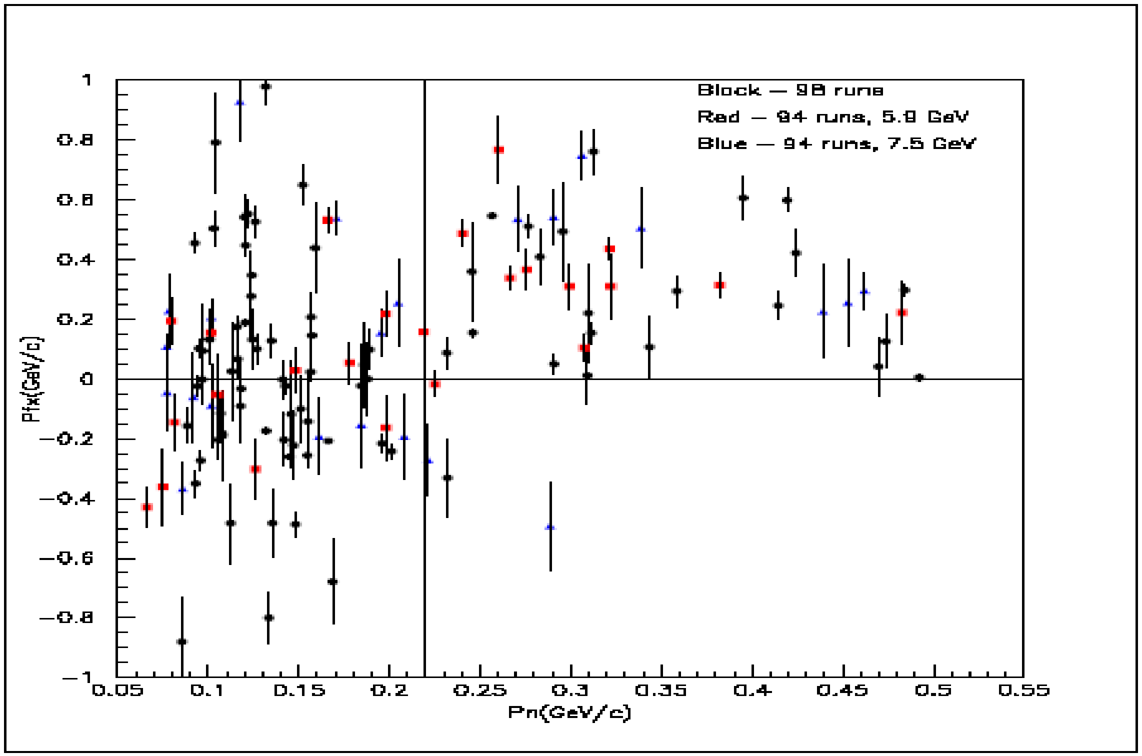

Figure I.5: The vertical component of the target nucleon momentum vs. the total neutron momentum.The positive vertical axis is the upward direction. The events shown are for triple coincidences of the neutron with the two high energy protons emerging from the QE C$(p, 2p)$ reaction. The squares are for the 5.9 GeV/c incident beam and the triangles are for 7.5 GeV/c. The dots are preliminary unpublished data from the 1998 runing period. We associate the events in the upper right corner with NN SRC.

Correlations

arXiv:0908.0062v1 [nucl-ex] 2 Aug 2009

Short-Distance Structure of Nuclei

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[2] Tel Aviv University, Tel Aviv 69978, Israel

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Abstract.

One of Jefferson Lab's original missions was to further our understanding of the short-distance structure of nuclei. In particular, to understand what happens when two or more nucleons within a nucleus have strongly overlapping wave-functions; a phenomena commonly referred to as short-range correlations. Herein, we review the results of the (e, e'), $(e, e'p)$ and $(e, e'pN)$ reactions that have been used at Jefferson Lab to probe this short-distance structure as well as provide an outlook for future experiments. ‡

arXiv:0908.1514v1 [nucl-ex] 11 Aug 2009

Probing Cold Dense Nuclear Matter

R. Subedi,[1] R. Shneor,[2] P. Monaghan,[3] B. D. Anderson,[1] K. Aniol,[4] J. Annand,[5] J. Arrington,[6] H. Benaoum,[7,8] F. Benmokhtar,[9] W. Bertozzi,[3] W. Boeglin,[10] J.-P. Chen,[11] Seonho Choi,[12] E. Cisbani,[13] B. Craver,[14] S. Frullani,[13] F. Garibaldi,[13] S. Gilad,[3] R. Gilman,[11,15] O. Glamazdin,[16] J.-O. Hansen,[11] D. W. Higinbotham,[11*] T. Holmstrom,[17] H. Ibrahim,[18] R. Igarashi,[19] C.W. de Jager,[11] E. Jans,[20] X. Jiang,[15] L.J. Kaufman,[9,22] A. Kelleher,[17] A. Kolarkar,[23] G. Kumbartzki,[15] J. J. LeRose,[11] R. Lindgren,[14] N. Liyanage,[14] D. J. Margaziotis,[4] P. Markowitz,[10] S. Marrone,[24] M. Mazouz,[25] D. Meekins,[11] R. Michaels,[11] B. Moffit,[17] C. F. Perdrisat,[17] E. Piasetzky,[2] M. Potokar,[26] V. Punjabi,[27] Y. Qiang,[3] J. Reinhold,[10] G. Ron,[2] G. Rosner,[28] A. Saha,[11] B. Sawatzky,[14,29] A. Shahinyan,[30] S. Širca,[26,31] K. Slifer,[14] P. Solvignon,[29] V. Sulkosky,[17] G. M. Urciuoli,[13] E. Voutier,[25] J. W. Watson,[1] L.B. Weinstein,[18] B. Wojtsekhowski,[11] S. Wood,[11] X.-C. Zheng,[3,6,14] and L. Zhu[32]

The protons and neutrons in a nucleus can form strongly correlated nucleon pairs. Scattering experiments, where a proton is knocked-out of the nucleus with high momentum transfer and high missing momentum, show that in ^{12}C the neutron-proton pairs are nearly twenty times as prevalent as proton-proton pairs and, by inference, neutron-neutron pairs. This difference between the types of pairs is due to the nature of the strong force and has implications for understanding cold dense nuclear systems such as neutron stars.

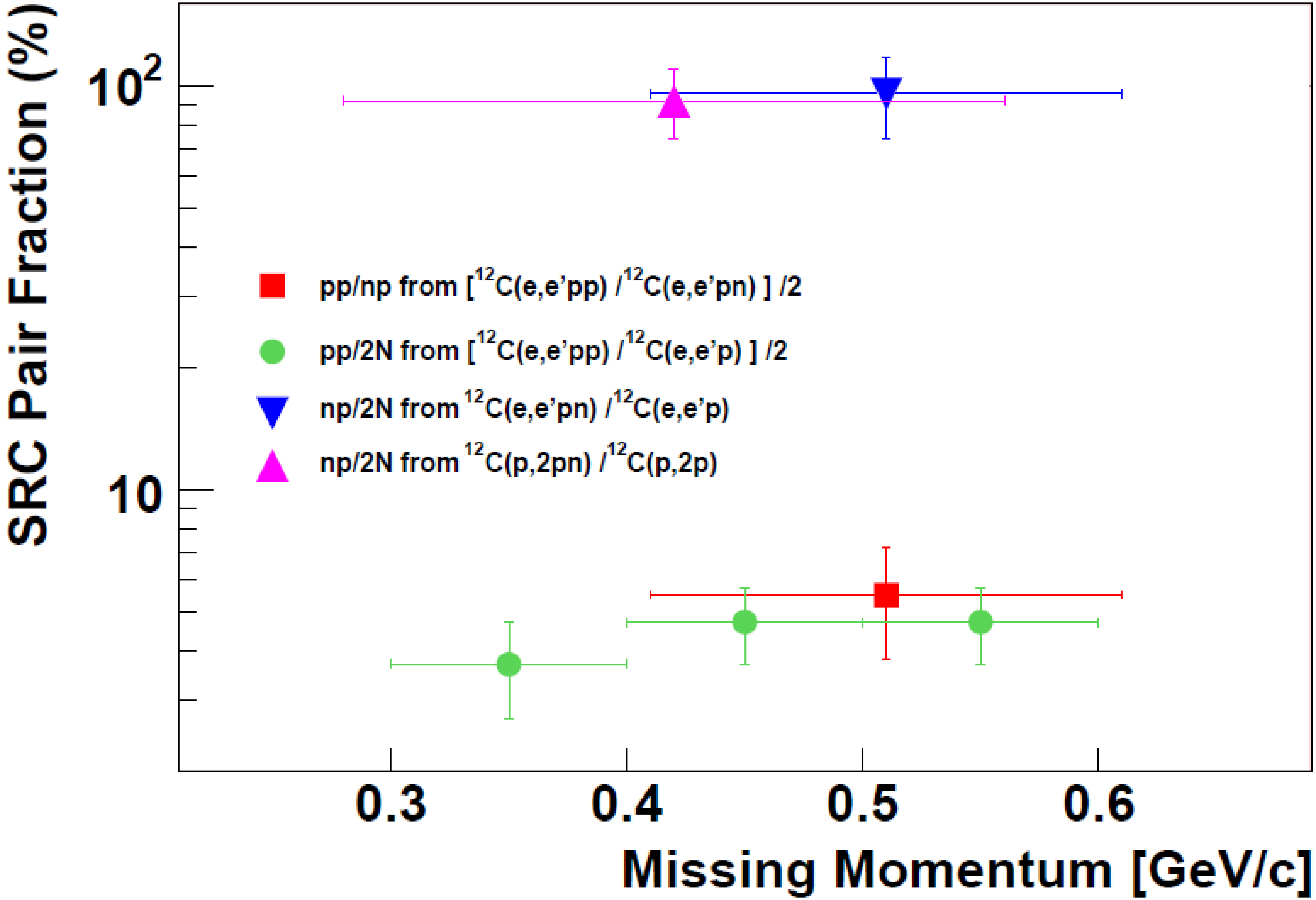
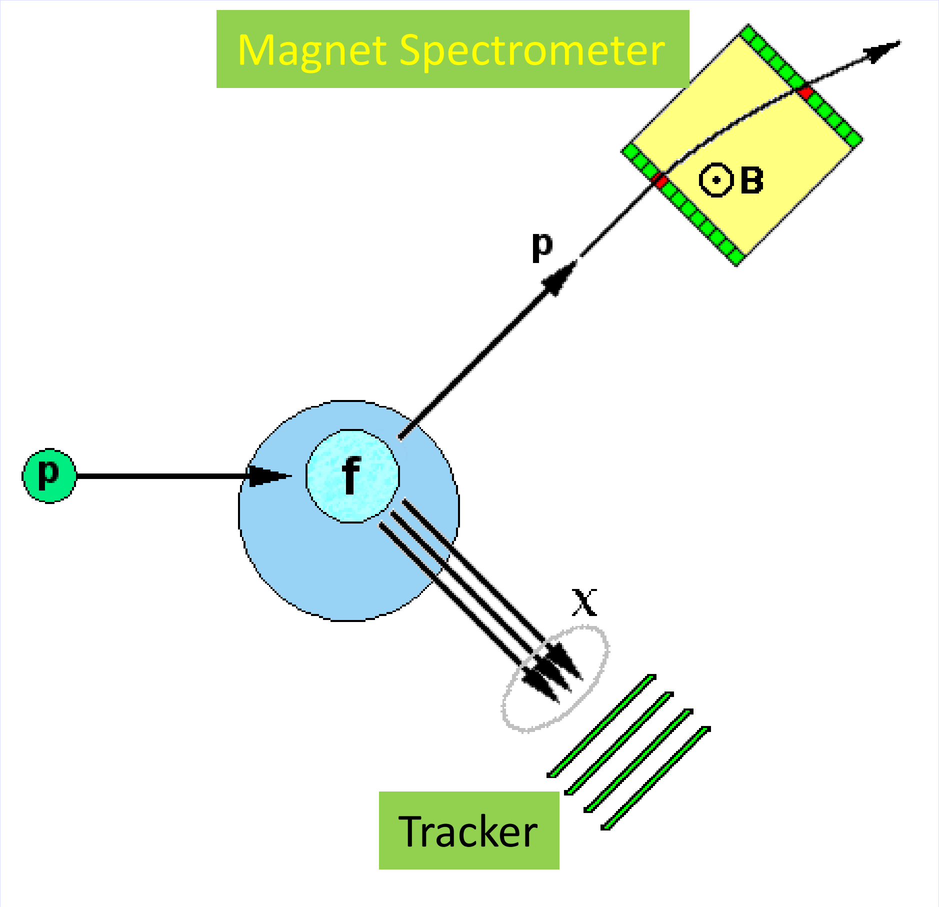


Figure 7. The fractions of correlated pair combinations in carbon as obtained from the $(e, e'pp)$ to $(e, e'pn)$ reactions [48], as well as from previous $(p, 2pn)$ data [45]. From Subedi R *et al.* (Hall A) 2008 *Science* **320** 1476. Reprinted with permission from AAAS.

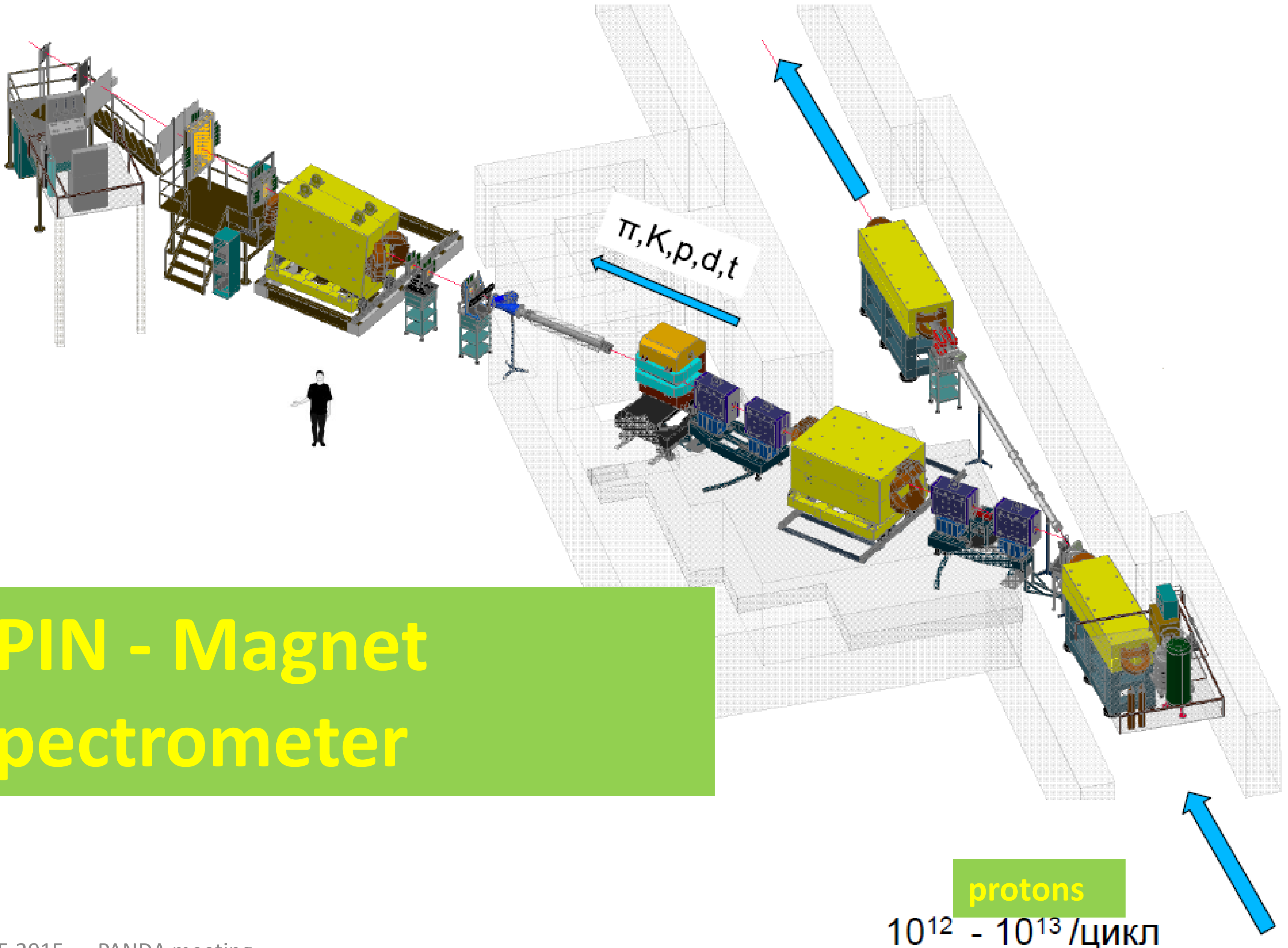
The Correlation Measurements with hadrons

pA->h+X

$\boxed{x_T \sim 1}$

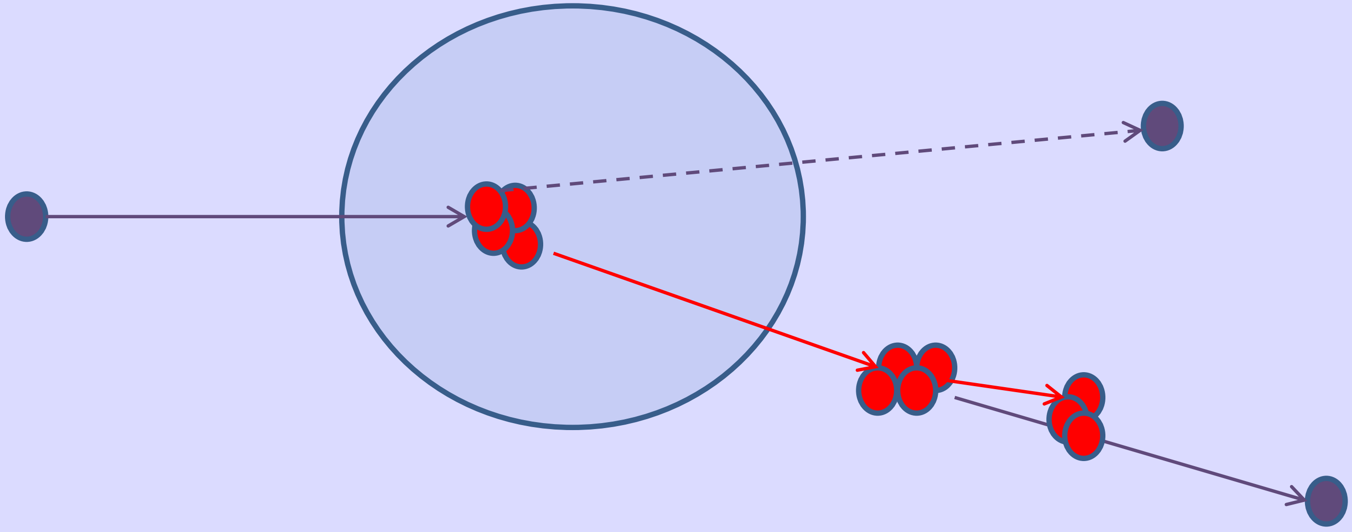


SPIN - Magnet Spectrometer



Flucton fragmentation – same side flow

Momentum up to 6.5 GeV/c and p_T up to 3.5 GeV/c

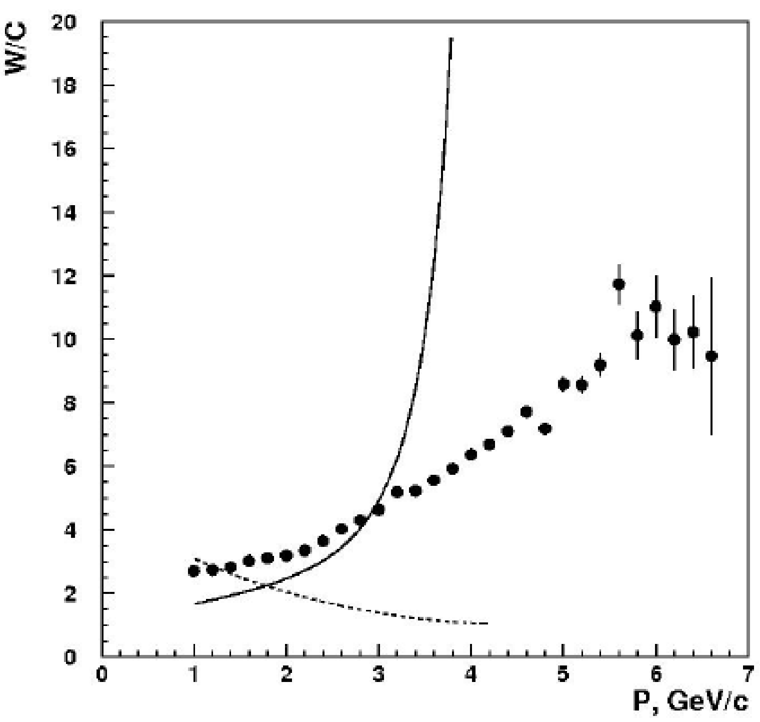


Physics of Atomic Nuclei, 2013, Vol. 76, No. 10, pp. 1213–1218

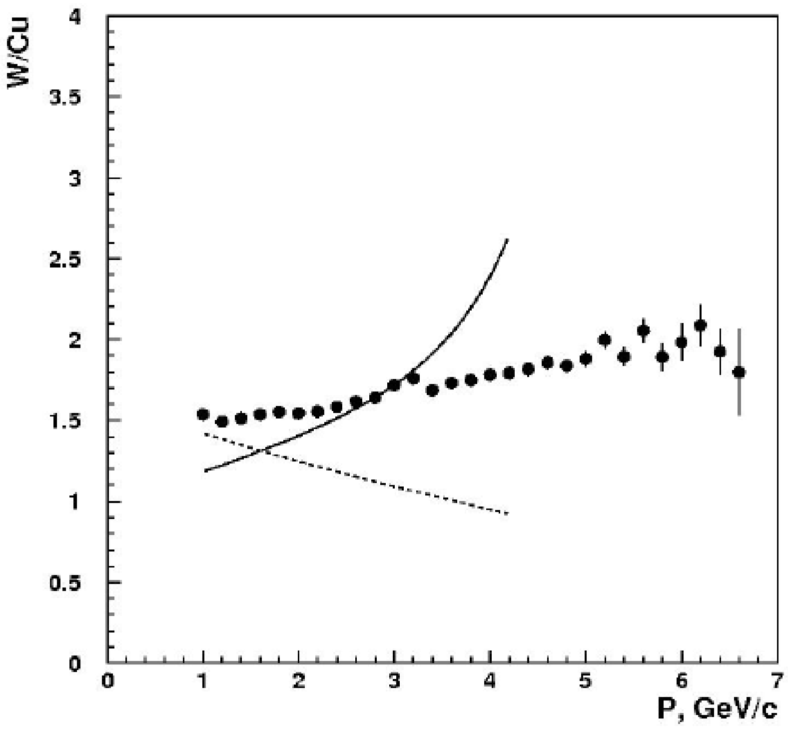
h^+ – spectrum

Сплошные кривые: HIJING 1.3 http://www-nsdth.lbl.gov/~xnwang/hijing/doc.html
Пунктирные кривые: UrQMD 3.3 http://urqmd.org/

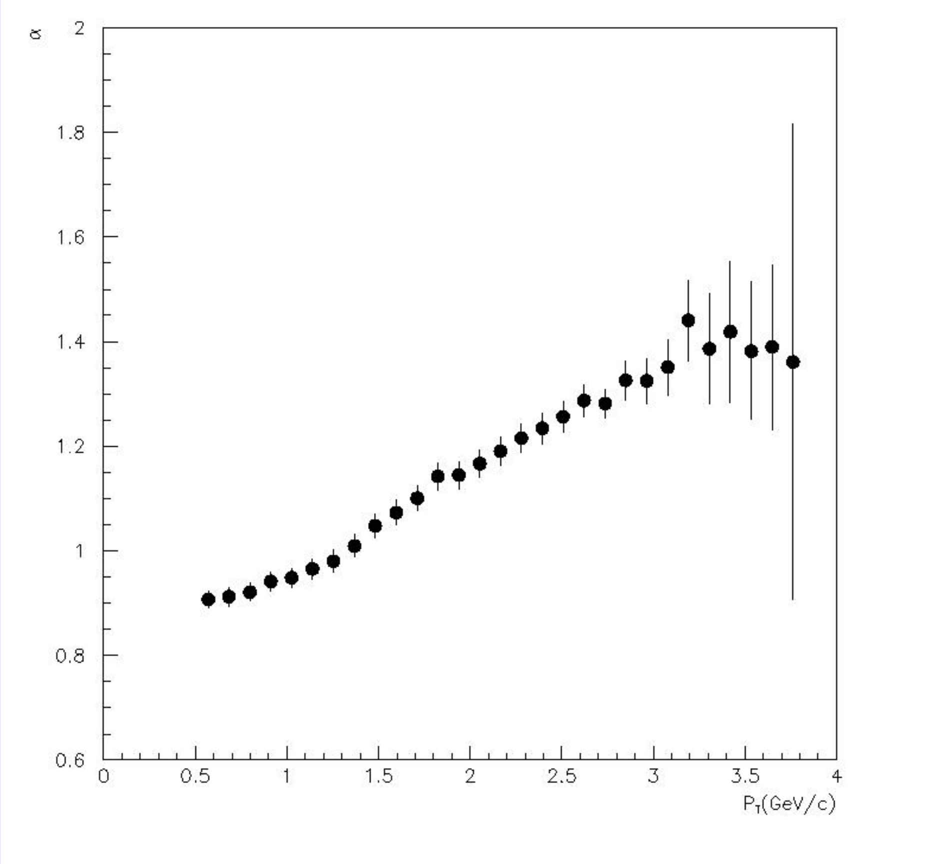
W / C



W / Cu



A-dependence

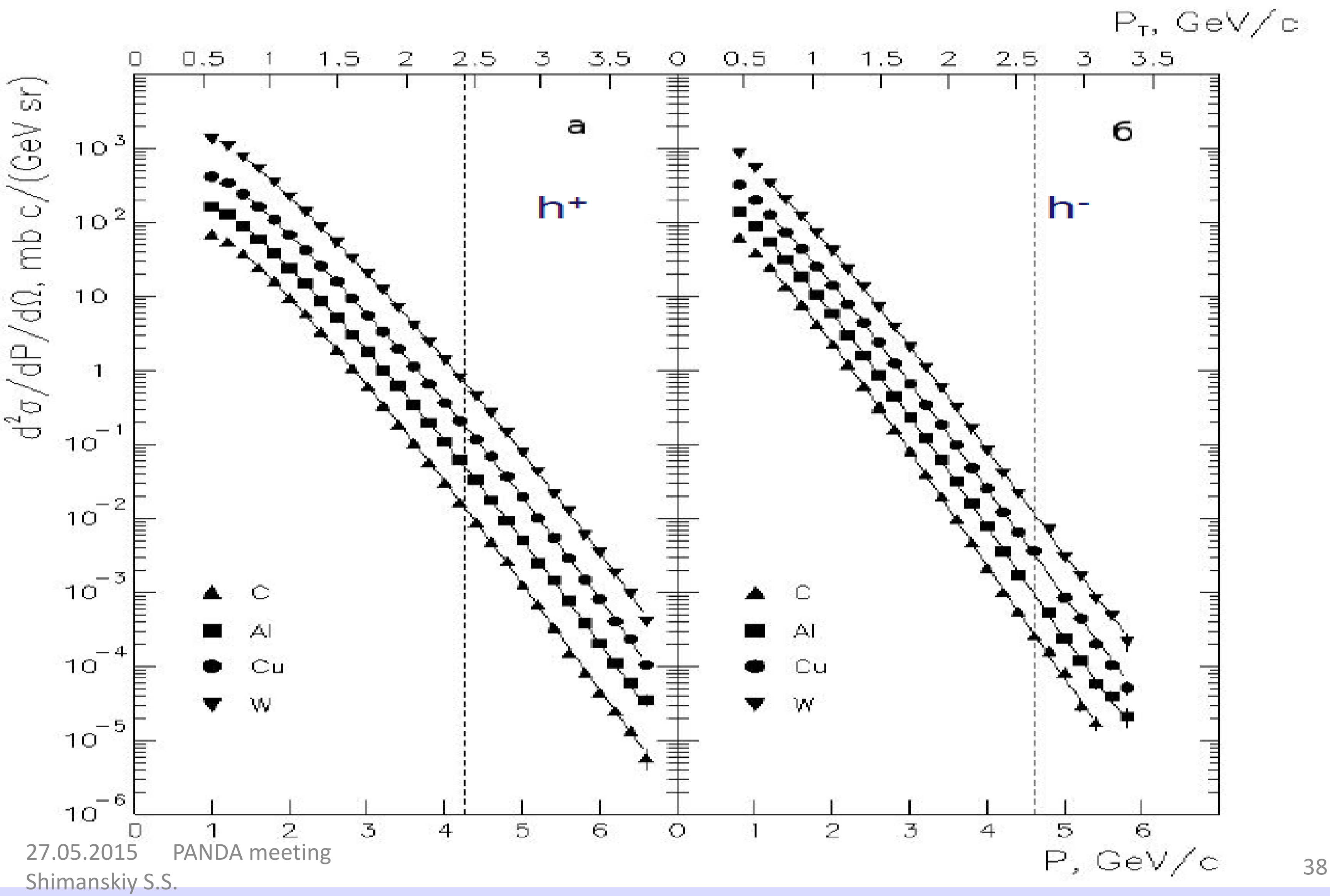


$$\sigma \sim A^{\alpha}$$

$$\alpha = \ln\left(\frac{\sigma_w}{\sigma_c}\right) / \ln\left(\frac{A_w}{A_c}\right)$$

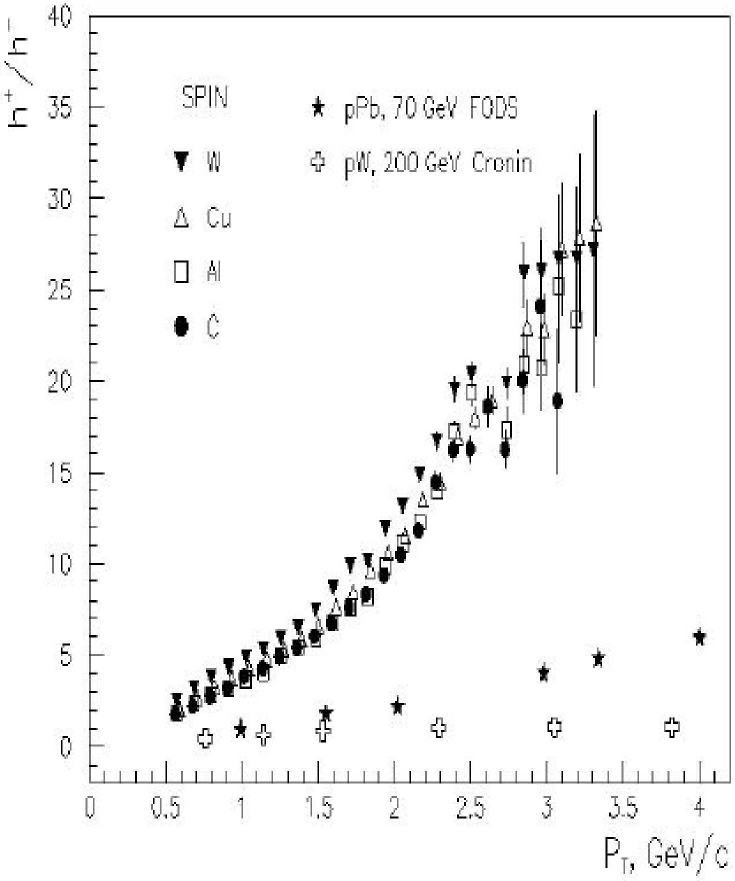
We deal with multinucleon configuration, but local this interaction?

[2012]

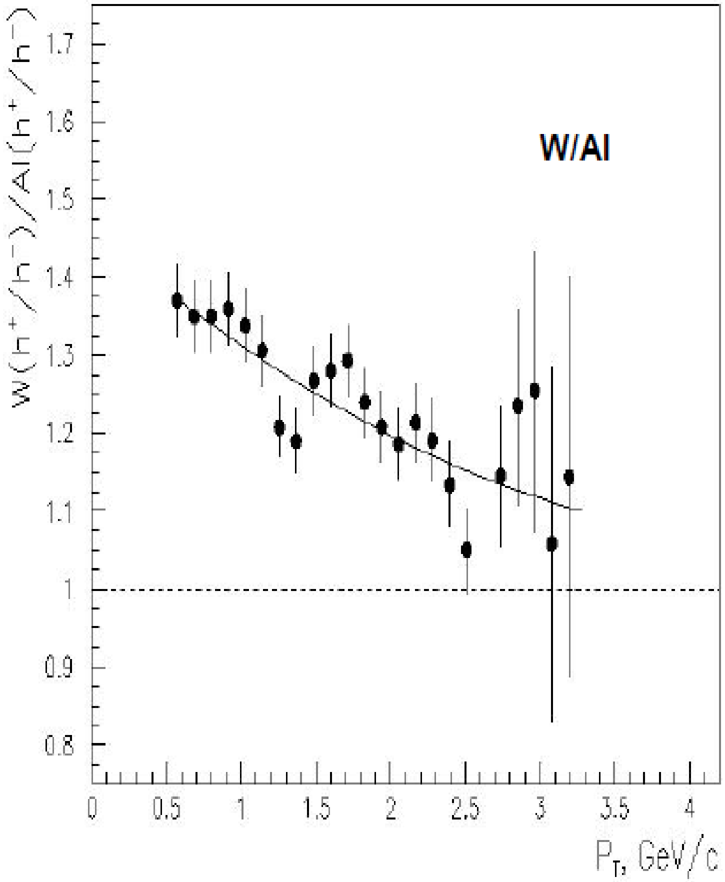


P_T, GeV/c
0
0.5
1
1.5
2
2.5
3
3.5
a
б
h^+
h^-
$d^2\sigma/dP/d\Omega$, mb c/(GeV sr)
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
C
Al
Cu
W
0
1
2
3
4
5
6
P, GeV/c

Ratios

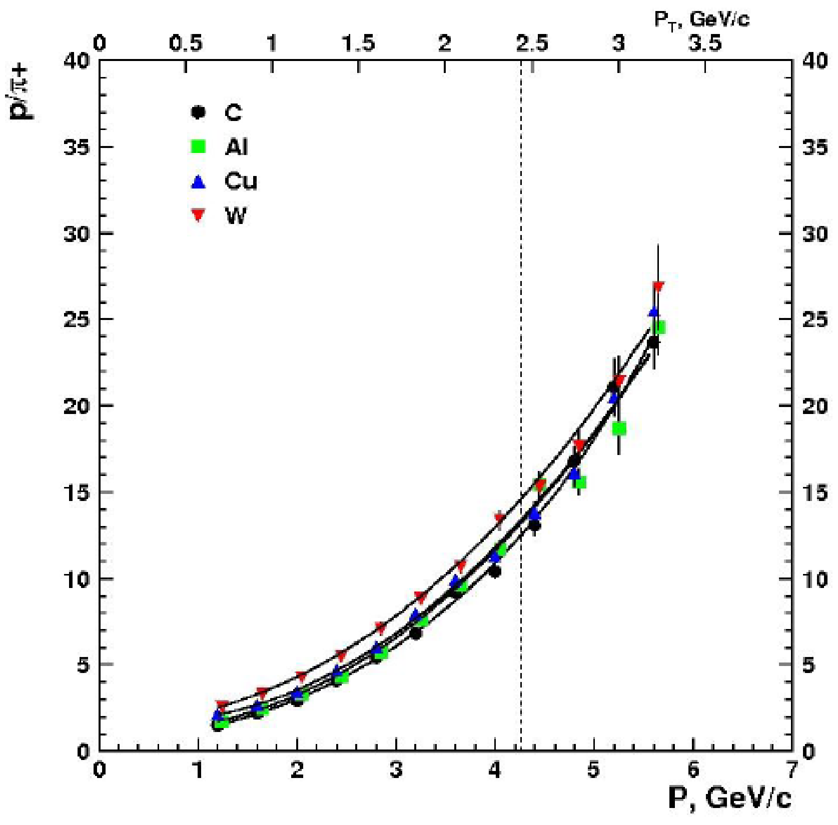


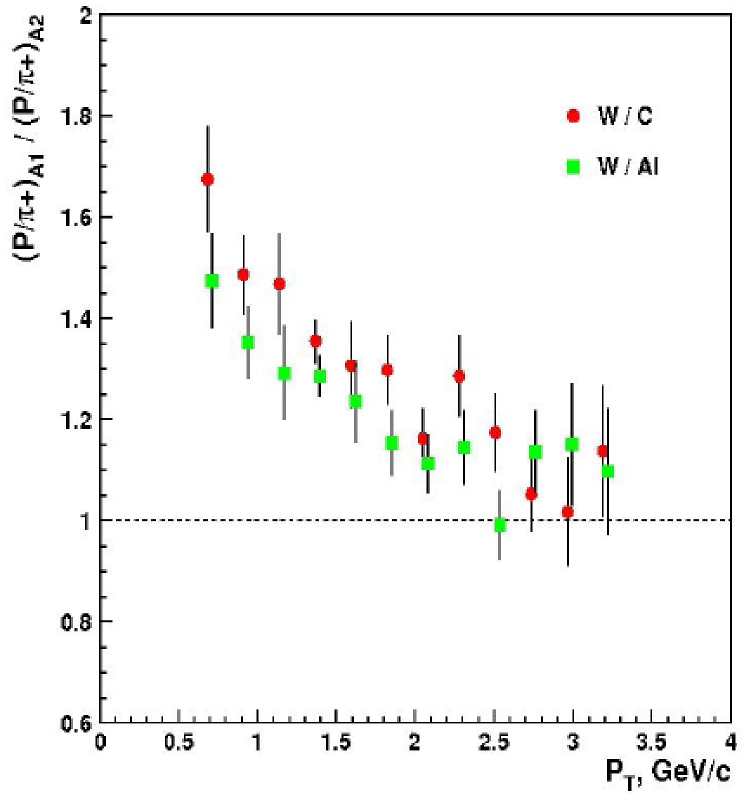
h^+/h^-
SPIN
W
Cu
Al
C
pPb, 70 GeV FODS
pW, 200 GeV Cronin
P_T, GeV/c



$W(h^+/h^-)/Al(h^+/h^-)$
W/Al
P_T, GeV/c

Ratio p/π^+ (2013)

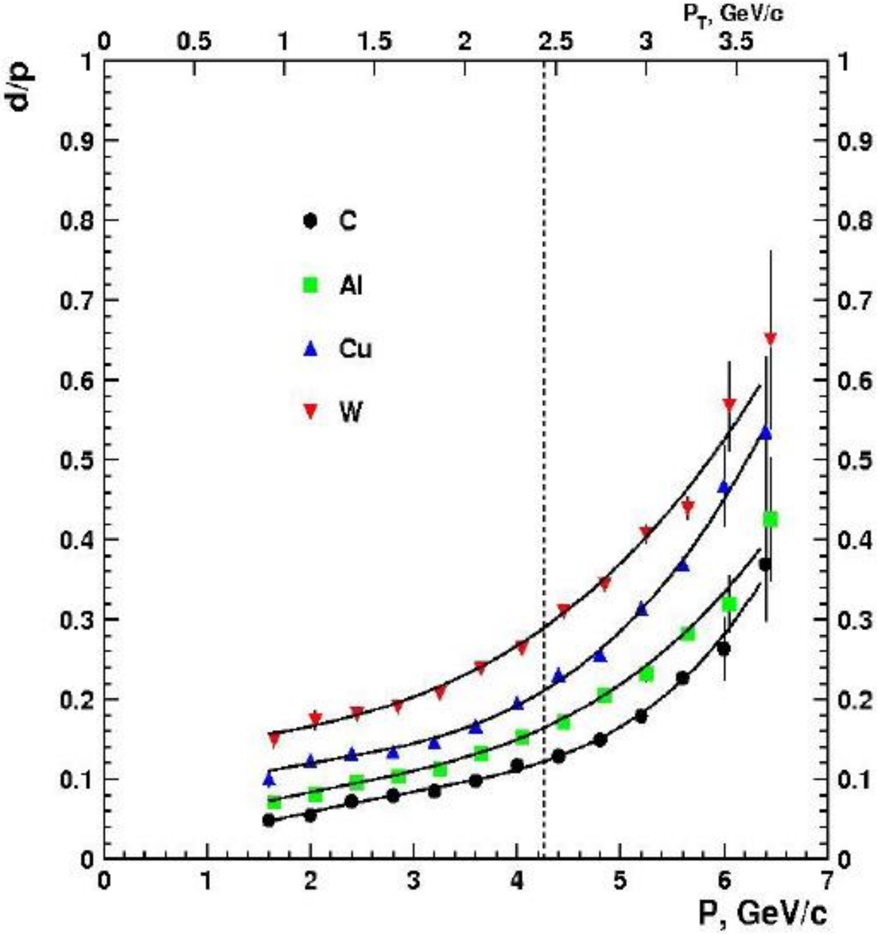


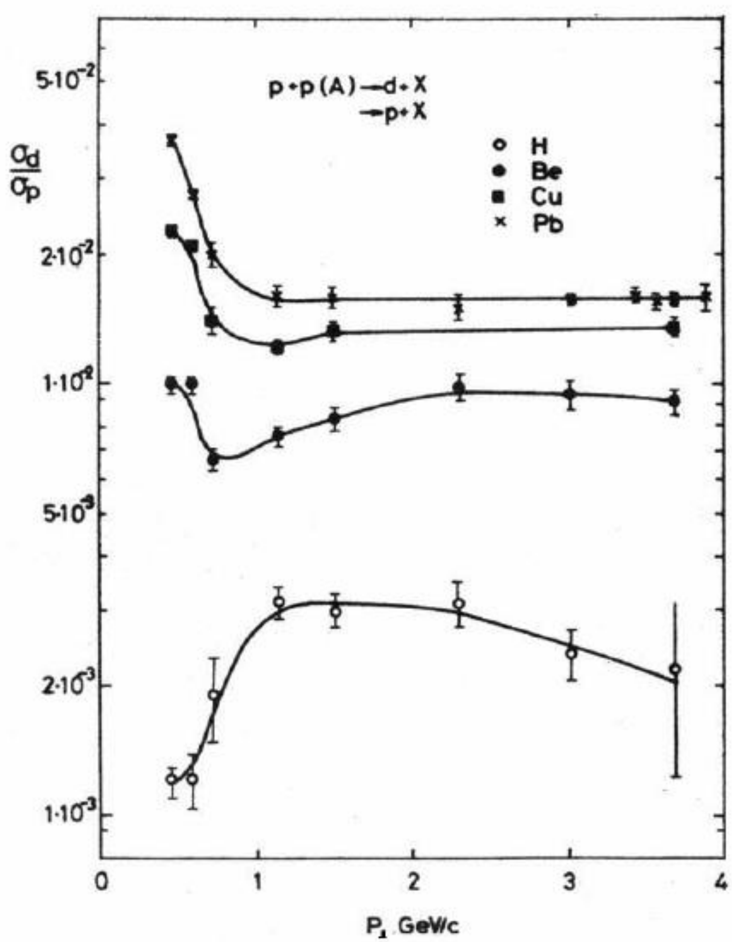


SPIN data

Ratio d/p

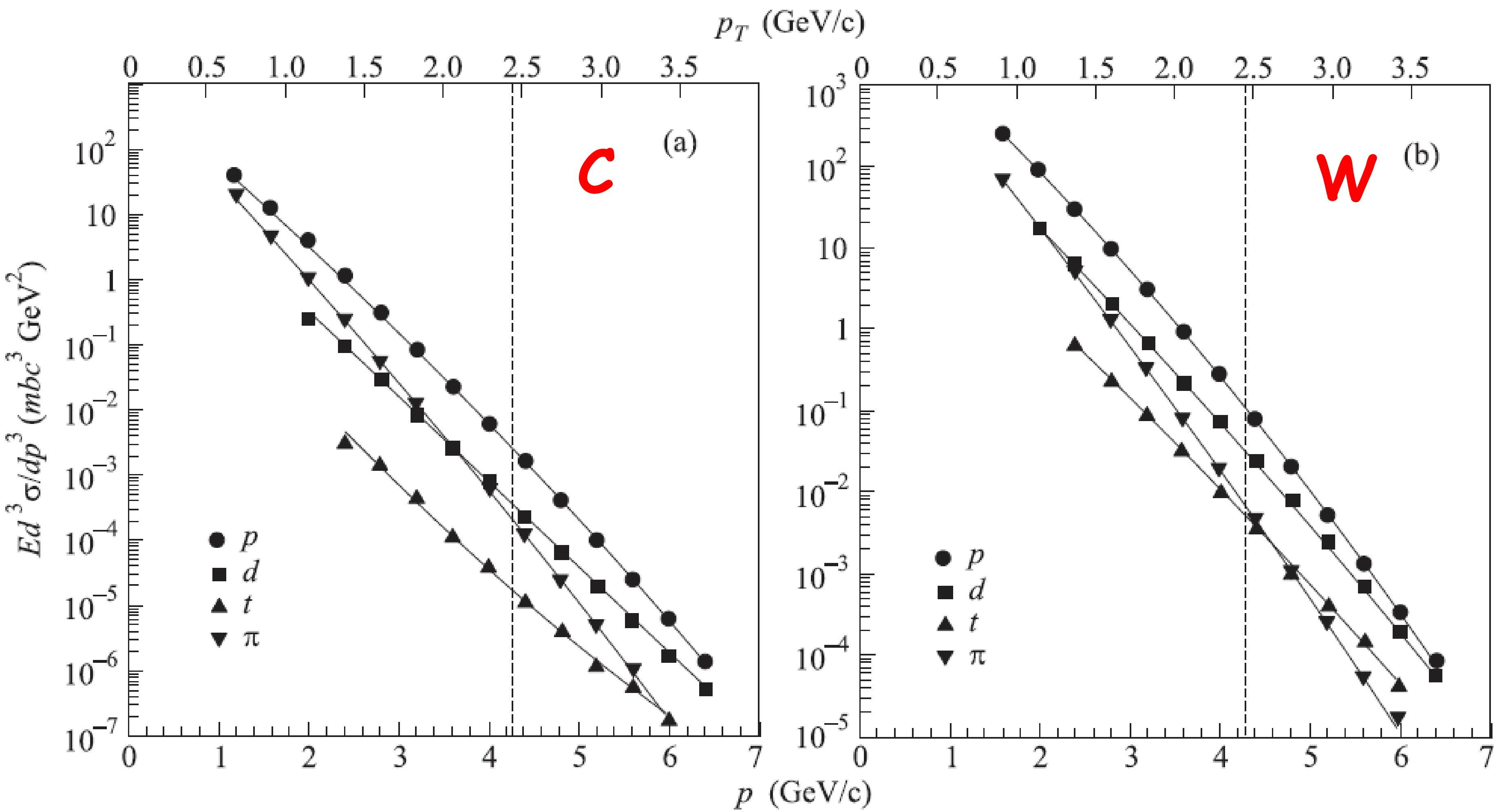
ФОДС В.В.Абрамов и др., ЯФ 45(5) (1987), 845–851





SPIN data JETP Letters (RUS), v.101, N 10, 746(2015)

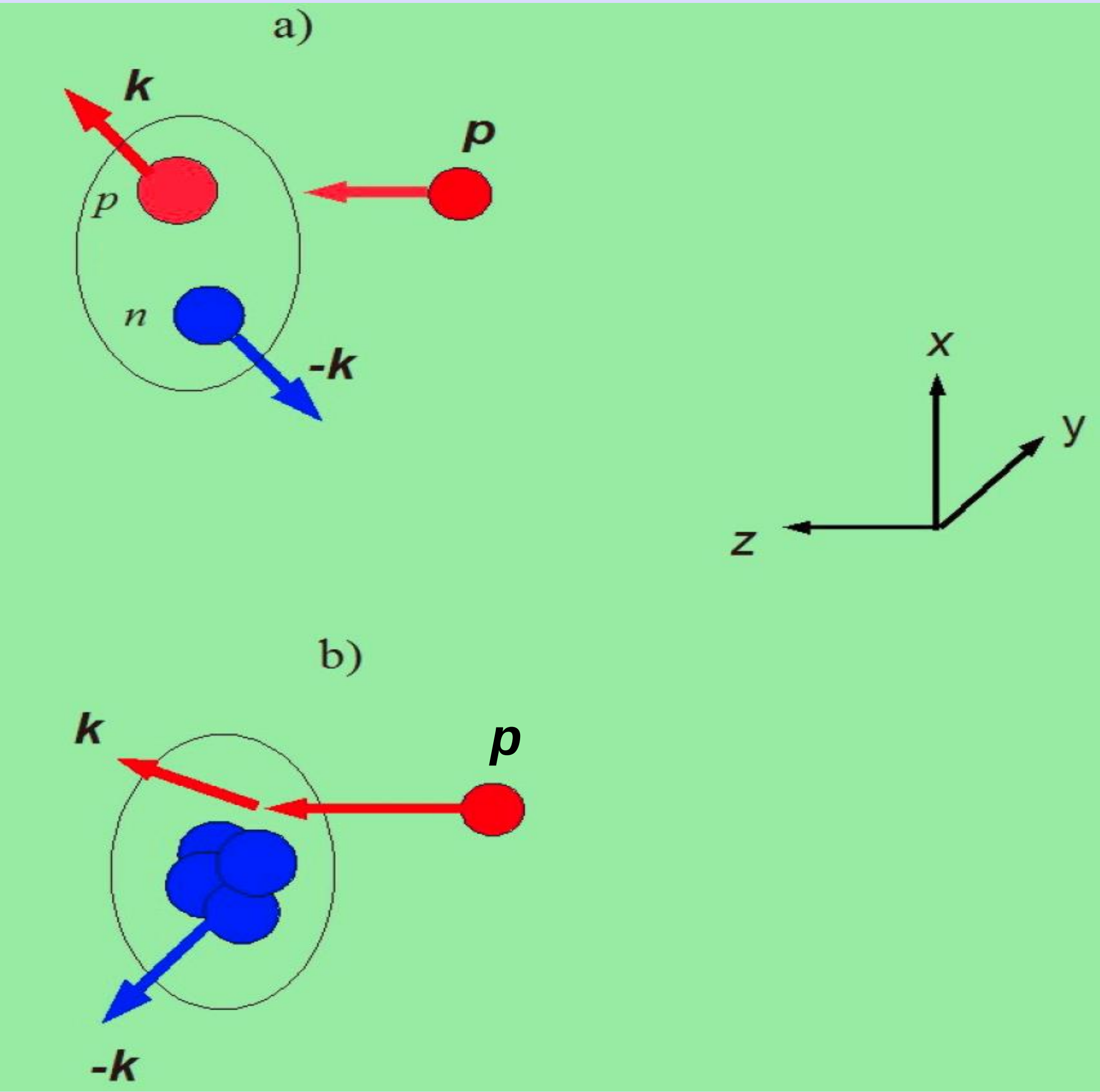
Published 25.05.2015



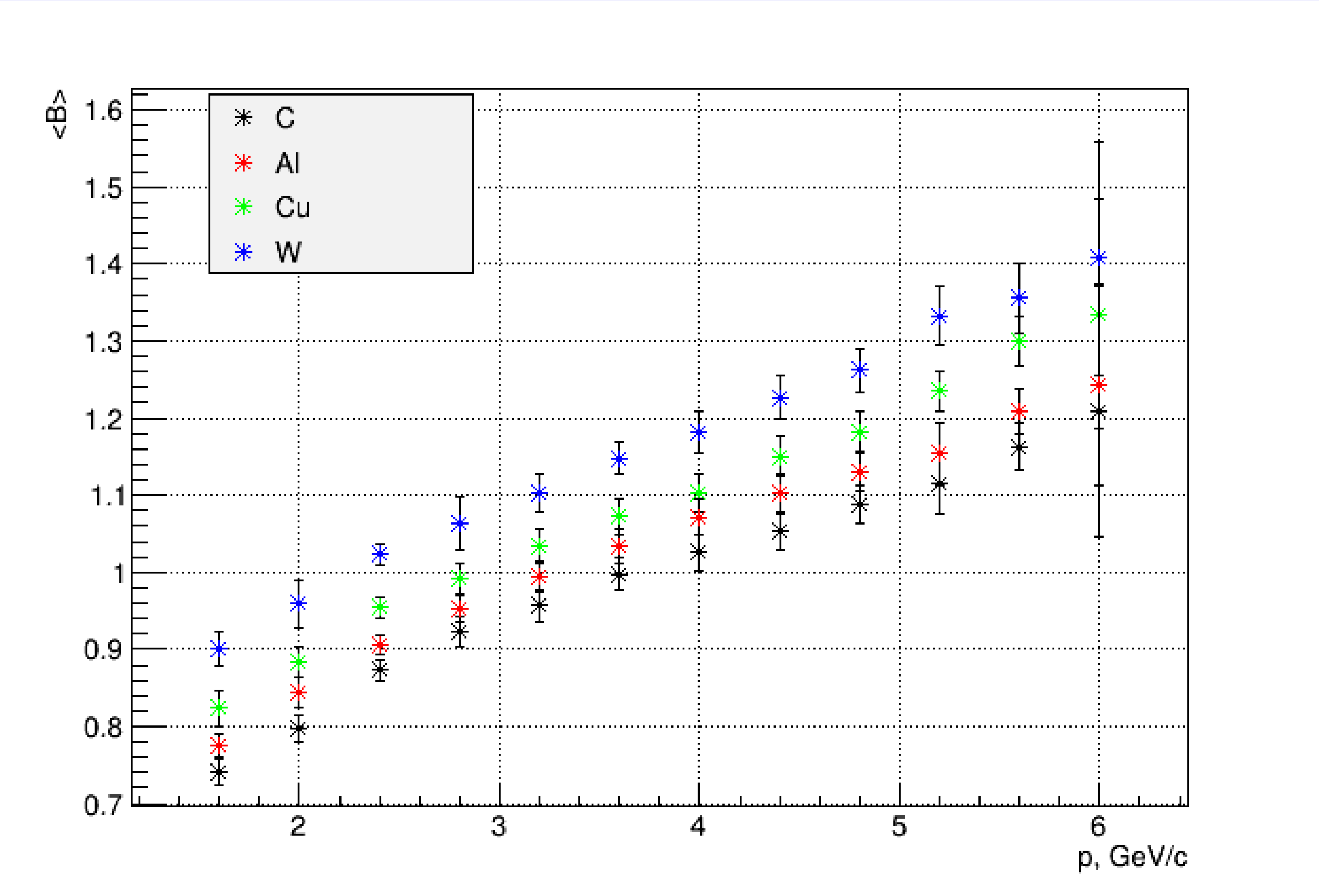
Knot out cold dense nuclear configurations

SRC configuration

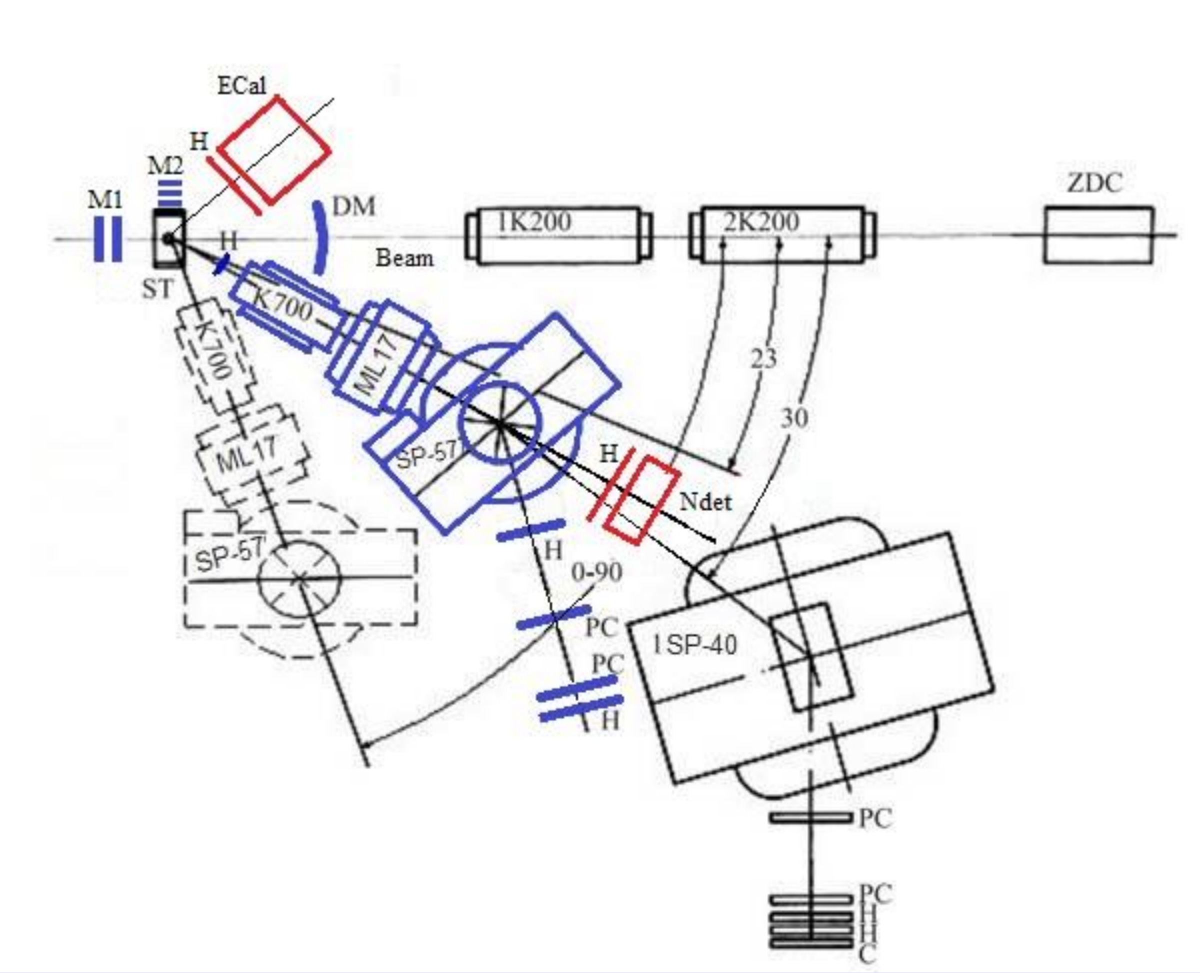
Multiquark configuration



Average baryon number <B>



Experiment MARUSYA-FLINT at JINR

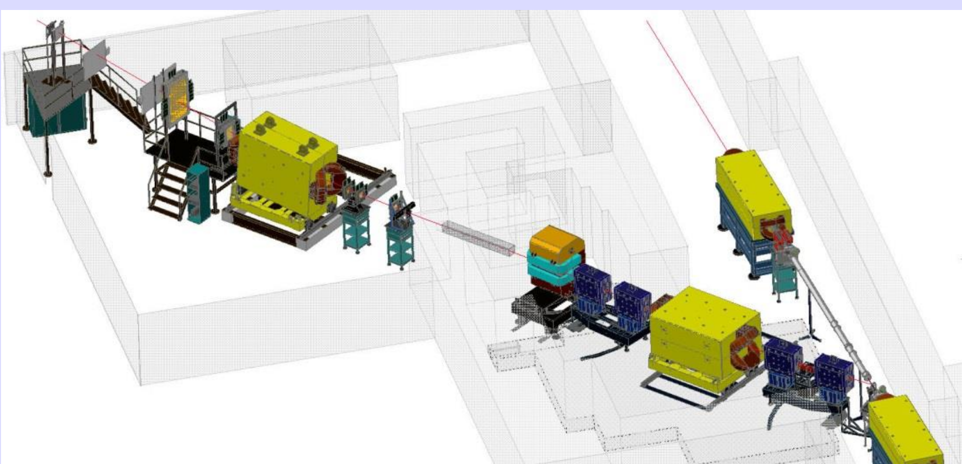


Scheme of experimental set-up MARUSYA-FLINT: ST - target station,
M1, M2- scintillation monitors,
DM- multiplicity detectors,
H- scintillation hodoscopes,
ZDC - hadron calorimeter,
PC - proportional chambers,
C – cherenkov counter,
ML17, K100 - quadrupole lens,
SP-57, SP-40 - dipole magnets,
ECal - electromagnetic calorimeter

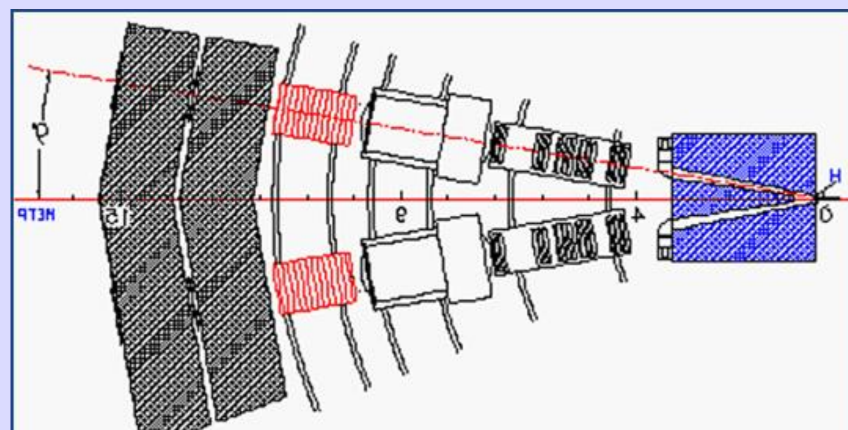
Magnetic spectrometer:
For P_t = 0,3-0,8 GeV/s used magnet SP-57
For P_t = 0,6-2 GeV/s used magnet SP-57 and SP-40
Coordinate system on scintillation hodoscopes provide resolution 2-5% in area 0,3-0,8 GeV/s

IHEP, Protvino

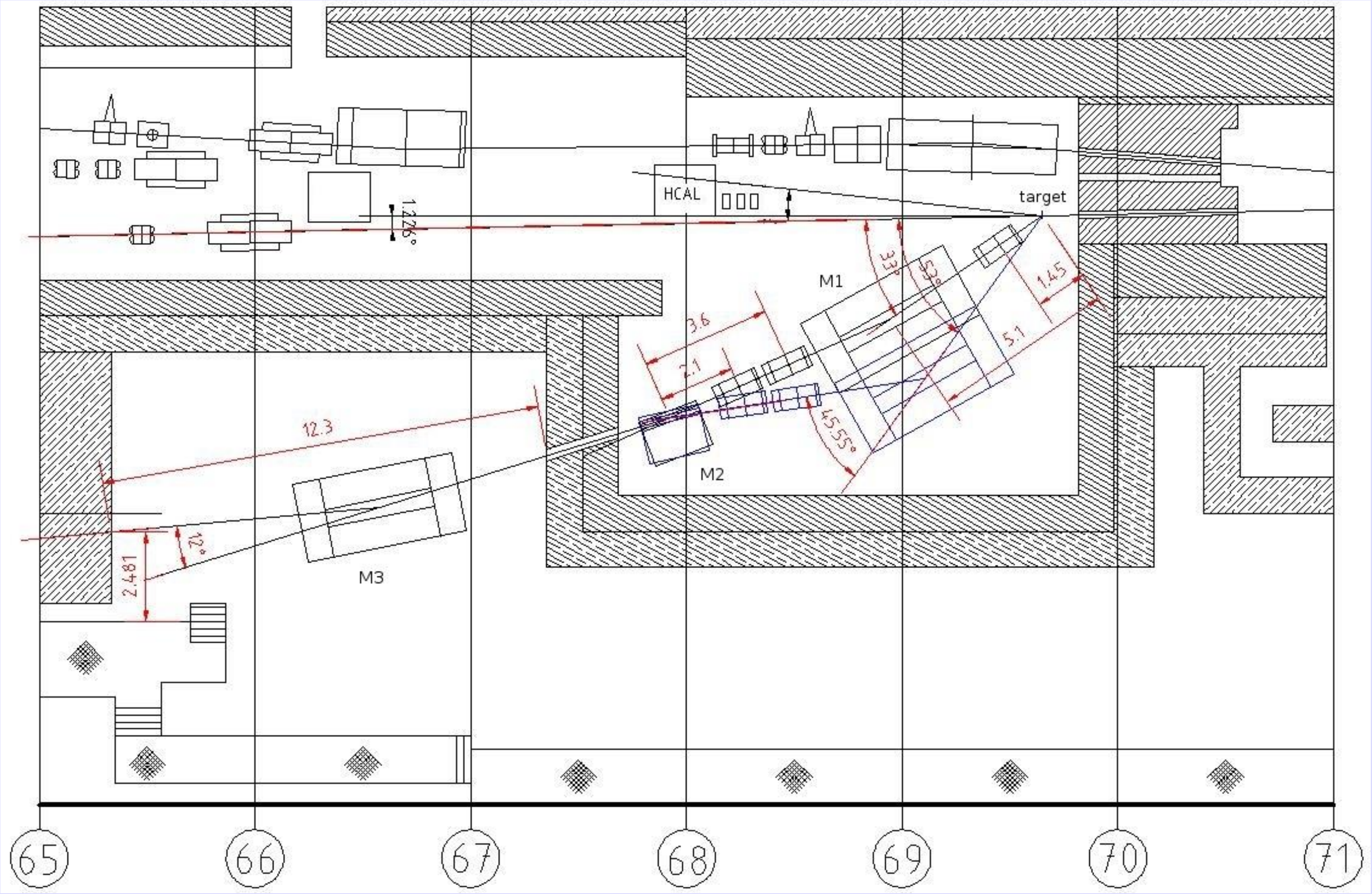
SPIN



FODS



Proposed structure of the two arms FLUKTON detector and location in 23rd proton beam line at U70



Available online at www.sciencedirect.com
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Nuclear Physics A ●●● (●●●●) ●●●–●●●
NUCLEAR PHYSICS A
www.elsevier.com/locate/nuclphysa

Towards the heavy-ion program at J-PARC

H. Sako [a,b,*], T. Chujo [c], T. Gunji [d], H. Harada [b], K. Imai [a], M. Kaneta [e], M. Kinsho [b], Y. Liu [f], S. Nagamiya [a,g,f], K. Nishio [a], K. Ozawa [f], P.K. Saha [b], T. Sakaguchi [h], S. Sato [a], J. Tamura [b]

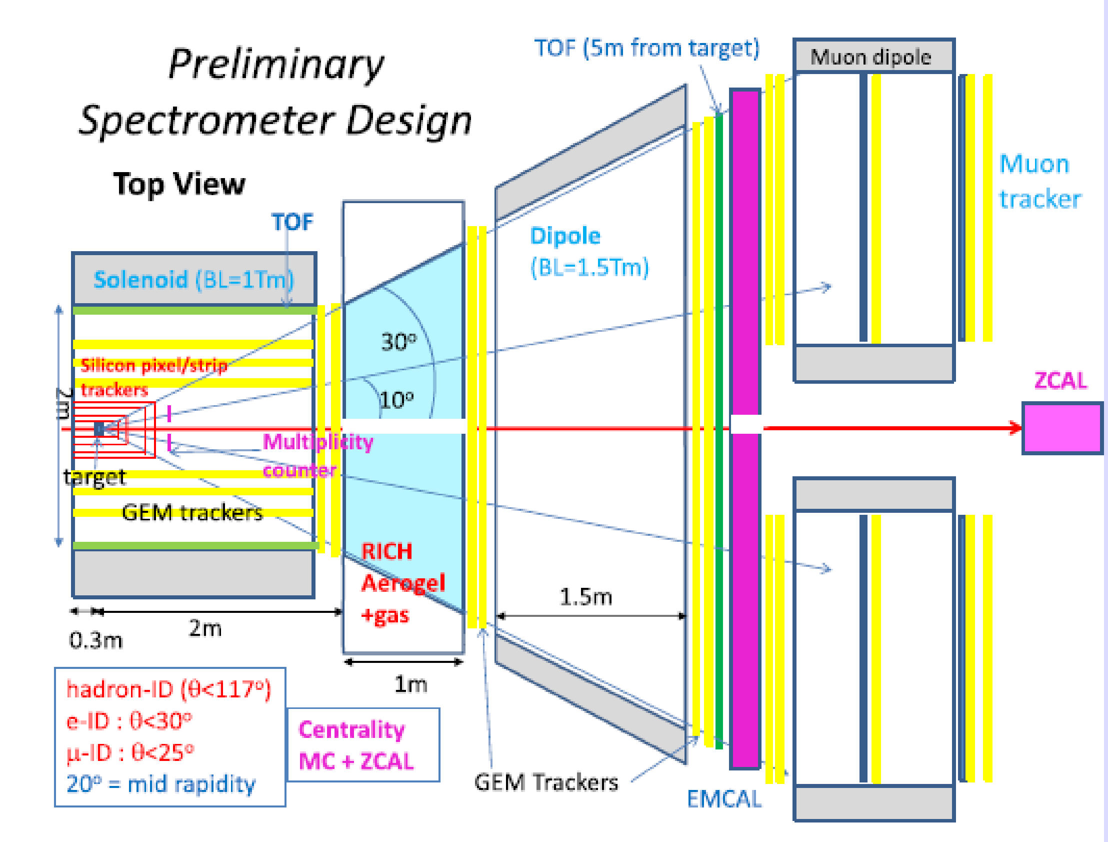
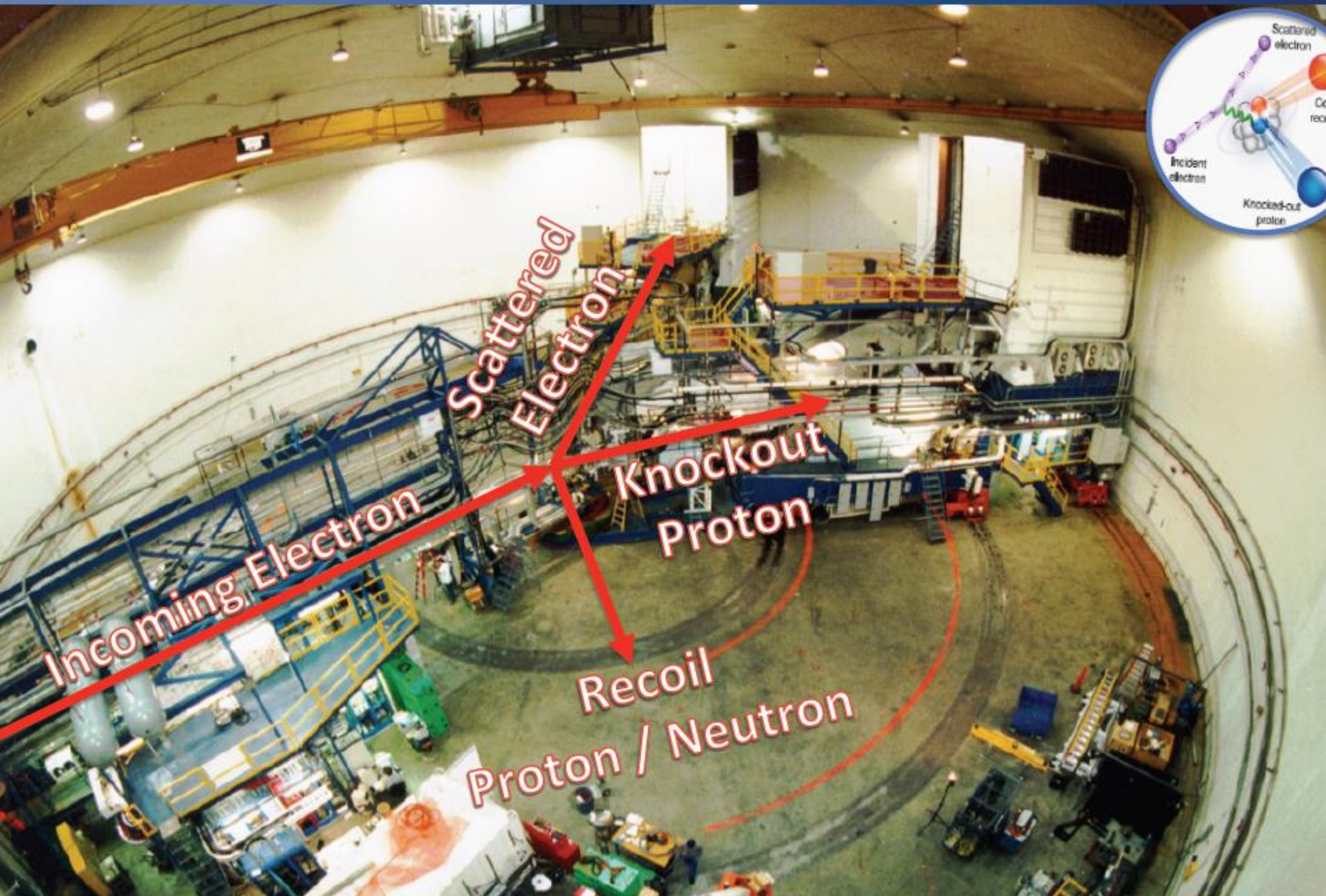
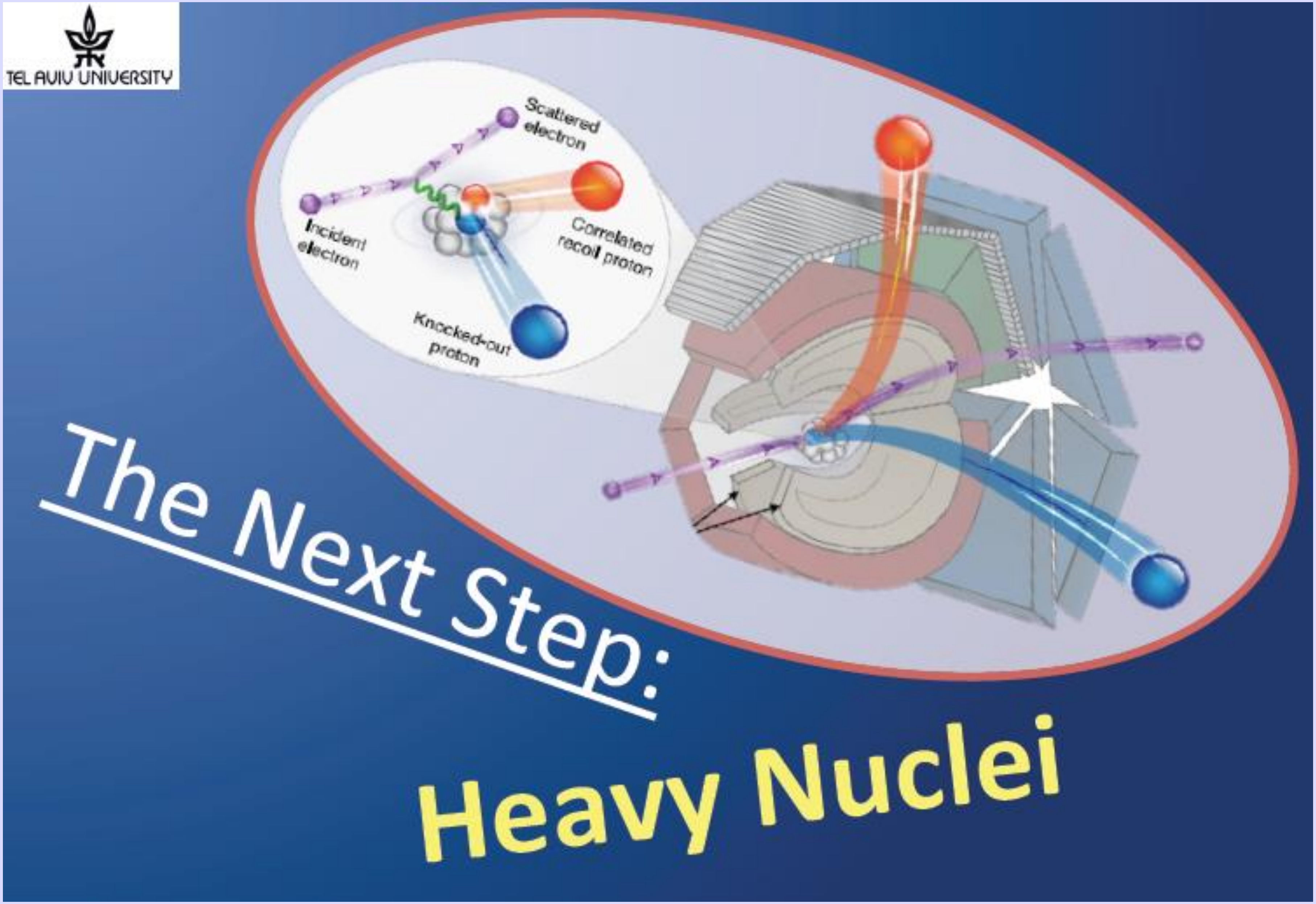


Fig. 2. A schematic view of the preliminary experimental setup.

Physics Tend to Fill the Open Space




TEL AVIV UNIVERSITY
Scattered electron
Incident electron
Correlated recoil proton
Knocked-out proton
The Next Step:
Heavy Nuclei

Main PANDA advantages

The unique beam – no worldwide (FNAL closed antiproton activity) and $\Delta p/p \sim 10^{-5}$.

The unique detector - $\Delta\Omega \sim 4\pi$ -exclusive reactions investigation (correlations, backward range); working at luminosity ~ 10^{32} cm^{-2} s^{-1} – the very rare event can be investigated; PID – close to full energy range and high momentum resolution.

Exotic Spectroscopy

arXiv:1007.4705v5 [hep-ph] 25 Sep 2010
Carlos Granados and Misak Sargsian

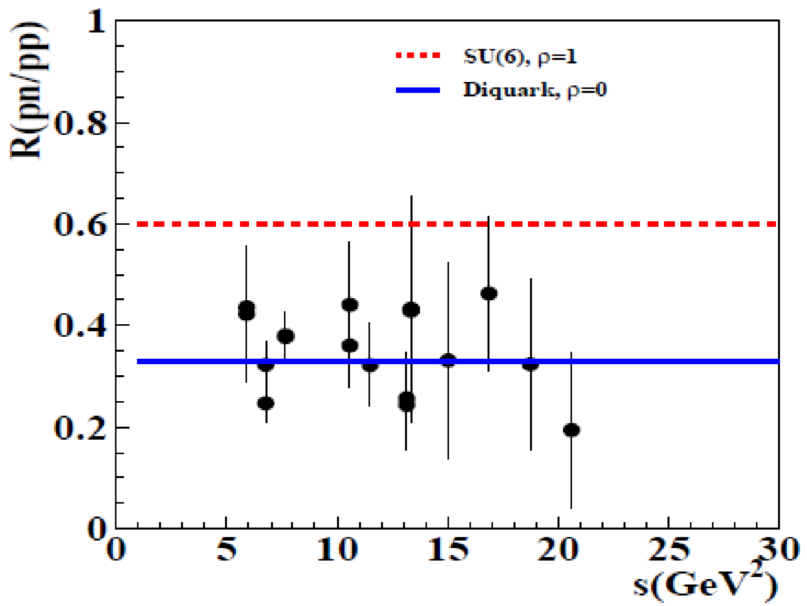


FIG. 2: (Color online) Ratio of the $pn \to pn$ to $pp \to pp$ elastic differential cross sections as a function of s at $\theta^N_{c.m.} = 90^0$.

$\bar{p}p$ studies at $x_T \sim 1$

$$\bar{p}p \to \bar{p}p$$
$$\bar{p}p \to \bar{n}n - ?$$

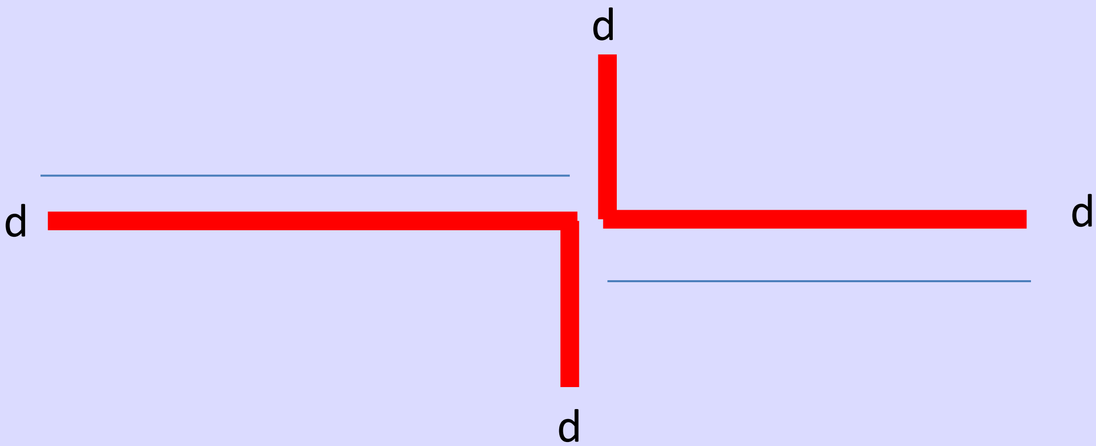
The counting rules and isotopic symmetry studies, $p_T \sim 2$ GeV/c anomaly(?)

$$\bar{p}p \to \bar{p}p + \pi\pi(KK)$$
$$\bar{p}p \to \bar{\Lambda}\Lambda + KK(\pi\pi,\mu\mu)$$
$$\bar{p}p \to \bar{\Delta}\Delta$$

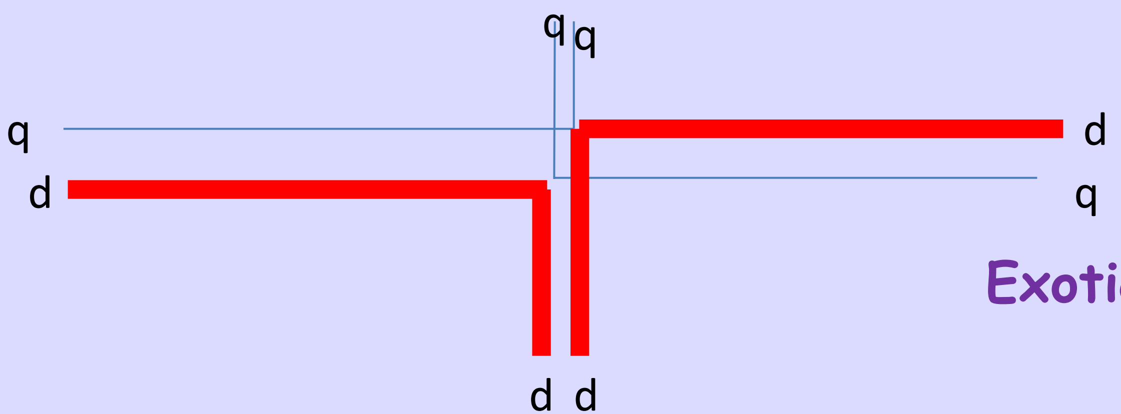
Detail vertexes studies:

$$q(\bar{q}) + \bar{q}(q) - (quark - antiquark)$$
$$q(\bar{q}) + \overline{qq}(qq) - (quark - antidiquark)$$
$$qq + \overline{qq} - (diquark - antidiquark)$$

pp - > pp + X, pp -> D + X reactions with diquarks



Diquark proof



Exotic states production

Kim's mechanisms

We must not allow the life FAIR turned into a FIR forest!

FAIR -> FIR

ЯРМАРКА -> ЕЛЬ

END

Local processes in NN kinematic

Production of anti-protons in the proton - nucleus interactions at 10.1-Gev/c. A.A. Sibirtsev, G.A. Safronov, G.N. Smitnov, Yu.V. Trebuchovsky (Moscow, ITEP). 1991. Published in Yad.Fiz. 53 (1991) 191-199

$$p + A \rightarrow h(0^0) + X$$

ИЗМЕРЕНИЕ СЕЧЕНИЙ ОБРАЗОВАНИЯ АДРОНОВ С ИМПУЛЬСОМ ДО 2 ГэВ/*c* В ПРОТОН-ЯДЕРНЫХ СТОЛКНОВЕНИЯХ ПРИ 70 ГэВ

БАРКОВ Л. М., ЗОЛОТОРЁВ М. С., КОТОВ В. И.[1], ЛЕБЕДЕВ П. К., МАКАРЬИНА Л. А.[2], МИШАКОВА А. П.[2], ОХАПКИН В. С., РЗАЕВ Р. А.[1], САХАРОВ В. П.[1], СМАХТИН В. П., ШИМАНСКИЙ С. С.

ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ СО АН СССР

(Поступила в редакцию 2 августа 1982 г.)

Sov.J.Nucl.Phys.37:732,1983

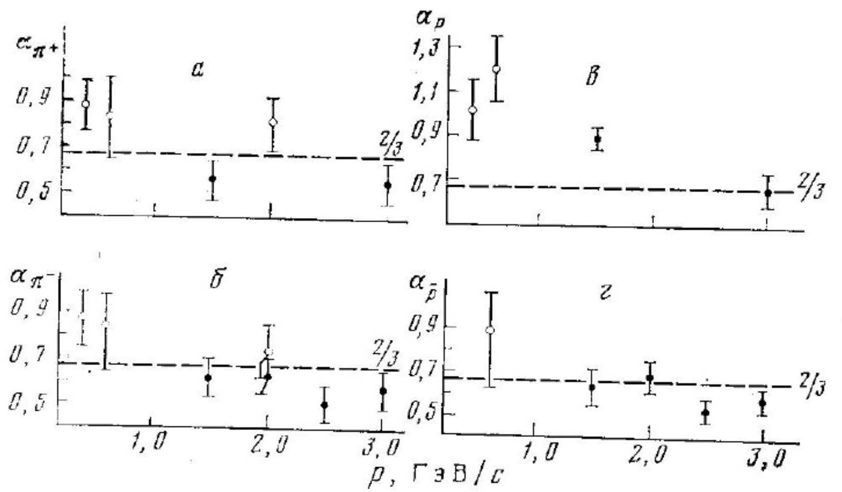


Рис. 4. Зависимость показателя α от импульса для положительных пионов (*а*), отрицательных пионов (*б*), протонов (*в*) и антипротонов (*г*) (● – [11], ○ – данная работа)

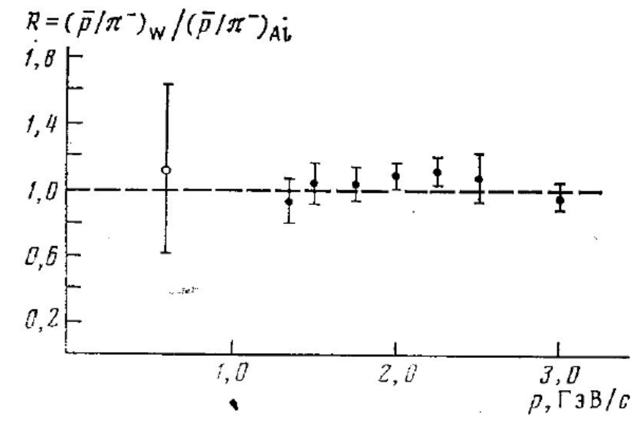


Рис. 6. Сравнение отношений выходов антипротонов и отрицательных пионов для W и Al мишеней в зависимости от импульса частиц (● – [11], ○ – данная работа)

PANDA experiment at FAIR

(JINR Participation)

JINR PAC, 2010

2.2. High p_T $p\bar{p}$ collisions and deep inelastic nuclear reactions with PANDA (S.S.Shimanskiy)

PANDA experiment provides an opportunity to study the properties of the color high density nuclear matter (CHDNM), which differs from Quark Gluon Plasma (QGP) state [1]. To detect the CHDNM one has to study the *p A* - collisions in kinematical region beyond the kinematical limits for interacting with free nucleons (named as cumulative processes).

We propose [7] to perform the measurement of three deep inelastic antiproton-nuclei processes (DINP):

- The first one is a DINP $\bar{p} + A \to \bar{p} + \langle mN \rangle$, where m is an average number of nucleons. The final state antiproton must have $x_T = \frac{2p_T}{\sqrt{s}} \sim 1$, where $s = (p_{\bar{p}} + p_N)^2$. The aim is to see the dependence on the cumulative number X. SRC mechanism predicts <m> ≈ 1 and no dependence on X.
- The second process is the subthreshold J/Ψ (and D-mesons) production: $\bar{p} + A \to J/\Psi + X \to \mu^+\mu^- + X$ at $E_{beam} \geq 2-3$ GeV. Dimuon pair must have $E^{\mu\mu} \geq 1.5$ GeV. The aim is to measure the cross section of this process which can be greater than the subthreshold cross section of antiproton production $p + A \to \bar{p} + X$ [8] which is already measured [4]. There is a prediction that the case $\sigma(\bar{p} + A \to J/\Psi + X) > \sigma(p + A \to \bar{p} + X)$ can be treated in favor of "flucton" hypothesis.

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]

[a] *Mississippi State University, Mississippi State, MS 39762, USA*
[b] *Argonne National Laboratory, Argonne, IL 60439, USA*
[c] *Pennsylvania State University, University Park, PA 16802, USA*

A R T I C L E   I N F O

Keywords:
QCD in Nuclei
Color transparency
Onset
Exclusive processes

A B S T R A C T

We review a unique prediction of Quantum Chromo Dynamics, called color transparency (CT), where the final (and/or initial) state interactions of hadrons with the nuclear medium must vanish for exclusive processes at high momentum transfers. We retrace the progress of our understanding of this phenomenon, which began with the discovery of the J/ψ meson, followed by the discovery of high energy CT phenomena, the recent developments in the investigation of the onset of CT at intermediate energies and the directions for future studies.

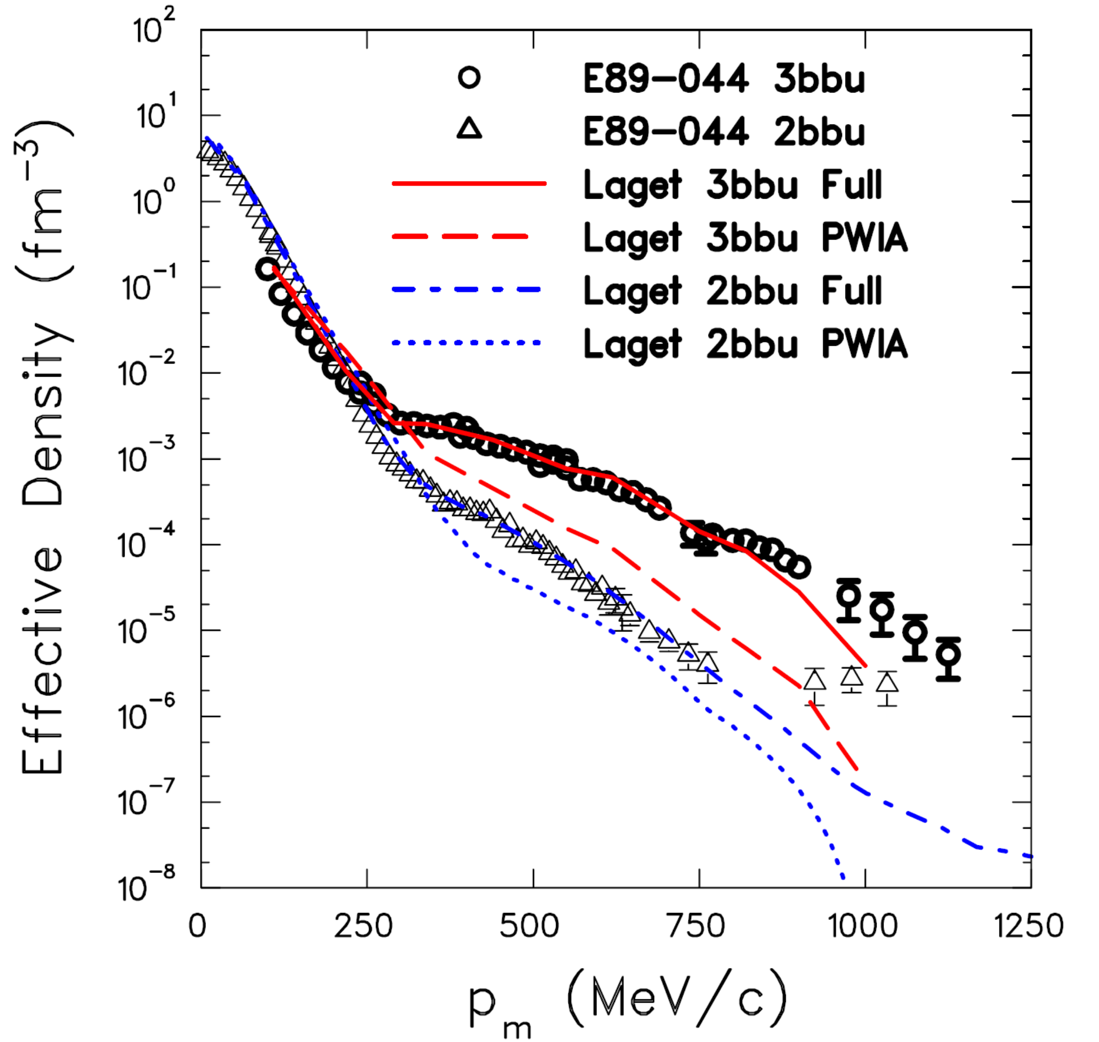


Figure 3. Proton effective momentum density distributions in ^{3}He extracted from $^3\mathrm{He}(e,e'p)pn$ three-body break-up (3bbu) is shown as the open black circles and the $^3\mathrm{He}(e,e'p)d$ two-body break-up (2bbu) is shown as open black triangles. The three-body break-up (3bbu) integration covers E_M from threshold to 140 MeV. The results are compared to calculations from J.-M. Laget [25] which explain the dominance of the continuum cross section at large missing momentum as a strong interference between short-range correlations and final-state interactions. Reprinted with permission from Benmokhtar F *et al.* (Hall A) 2005 *Phys. Rev. Lett.* **94** 082305. Copyright 2005 by the American Physical Society.

Fiz. Elem. Chast. At. Yadra. 2005. V. 36. P. 954

CURRENT EXPERIMENTS USING POLARIZED BEAMS OF THE JINR VBLHE ACCELERATOR COMPLEX

F. Lehar

DAPNIA, CEA/Saclay, Gif-sur-Yvette Cedex, France

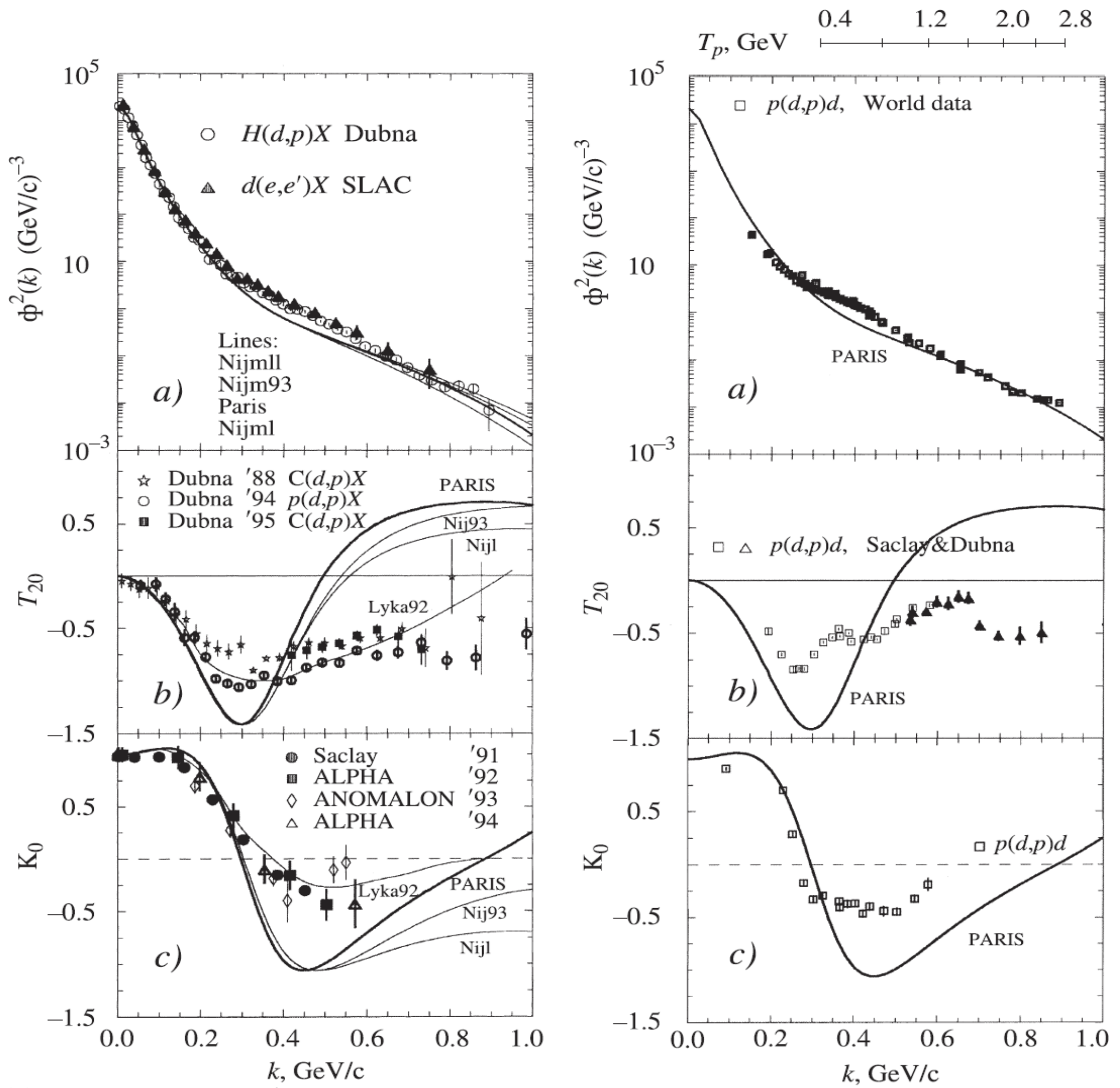


Рис. 5. Сводка данных экспериментов по фрагментации (слева) и упругому рассеянию «назад» (справа) поляризованных и неполяризованных дейтронов

RHIC press release after analysis of first 3 years

BROOKHAVEN NATIONAL LABORATORY

Contact: Karen McNulty Walsh, (631) 344-8350 or Mona S. Rowe, (631) 344-5056

RHIC Scientists Serve Up "Perfect" Liquid

New state of matter more remarkable than predicted -- raising many new questions

April 18, 2005

TAMPA, FL -- The four detector groups conducting research at the Relativistic Heavy Ion Collider (RHIC) -- a giant atom "smasher" located at the U.S. Department of Energy's Brookhaven National Laboratory -- say they've created a new state of hot, dense matter out of the quarks and gluons that are the basic particles of atomic nuclei, but it is a state quite different and even more remarkable than had been predicted. In peer-reviewed papers summarizing the first three years of RHIC findings, the scientists say that instead of behaving like a gas of free quarks and gluons, as was expected, the matter created in RHIC's heavy ion collisions appears to be more like a liquid.

2-х партонный + 3-х партонный + …

PDF

$0 < x < 1$

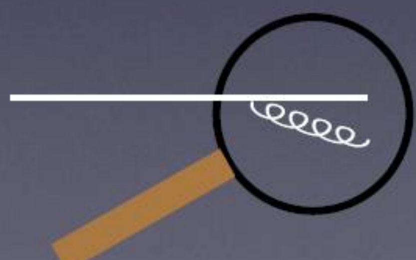
probability to find a "parton" *i* of momentum $x\,p$

parton distribution function $f_i(x_i)$

p p collision = sum of parton-parton collision

$$\sigma = \int_0^a dx_1 \int_0^1 dx_2 f_i(x_1) f_i(x_2) \sigma(ij \to X)$$

but if you look closely (high Q^2), partons split further



DGLAP equation

$$\frac{df_i(x)}{dQ^2} = \int_x^1 dx' f_j(x') P(j \to i + X)$$

СБОРНИК

КРАТКИЕ СООБЩЕНИЯ ПО ФИЗИКЕ

№ 1,January1971

№ 1 январь 1971

It is possible to obtain the record high energy particle beams by means of accelerating the heavy nuclei with large charges

АКАДЕМИЯ НАУК СССР

Ордена Ленина

Физический институт им П.Н. Лебедева

МАСШТАБНАЯ ИНВАРИАНТНОСТЬ АДРОННЫХ СТОЛКНОВЕНИЙ И ВОЗМОЖНОСТЬ ПОЛУЧЕНИЯ ПУЧКОВ ЧАСТИЦ ВЫСОКИХ ЭНЕРГИЙ ПРИ РЕЛЯТИВИСТСКОМ УСКОРЕНИИ МНОГОЗАРЯДНЫХ ИОНОВ

А. М. Балдин

Пучки частиц высоких энергий до последнего времени получались исключительно на протонных и электронных ускорителях, т.е. при ускорении частиц, обладающих единичным зарядом. Ускорение частиц, обладающих зарядом большим единицы, как известно, в принципе дает возможность получить энергию ускоряемых частиц (при одинаковых параметрах ускорителя) большую, чем энергия протонов, в число раз, равное кратности заряда. Так, например, на Дубненском синхрофазотроне, рассчитанном на получение протонов с энергией 10 Гэв, можно получить ядра гелия с энергией 20 Гэв, а ядра неона (заряд 10 e) с энергией 100 Гэв. Возникает естественный вопрос, не получатся ли в результате столкновения с мишенью ядер, например, неона, обладающих энергией 100 Гэв, пучки вторичных частиц, полученные пока только на Серпуховском ускорителе? Утвердительный ответ на этот вопрос означал бы, что с помощью ускорения тяжелых ядер, обладающих более высоким зарядом, можно было бы сравнительно дешевым способом в короткие сроки получить пучки частиц рекордно высоких энергий.

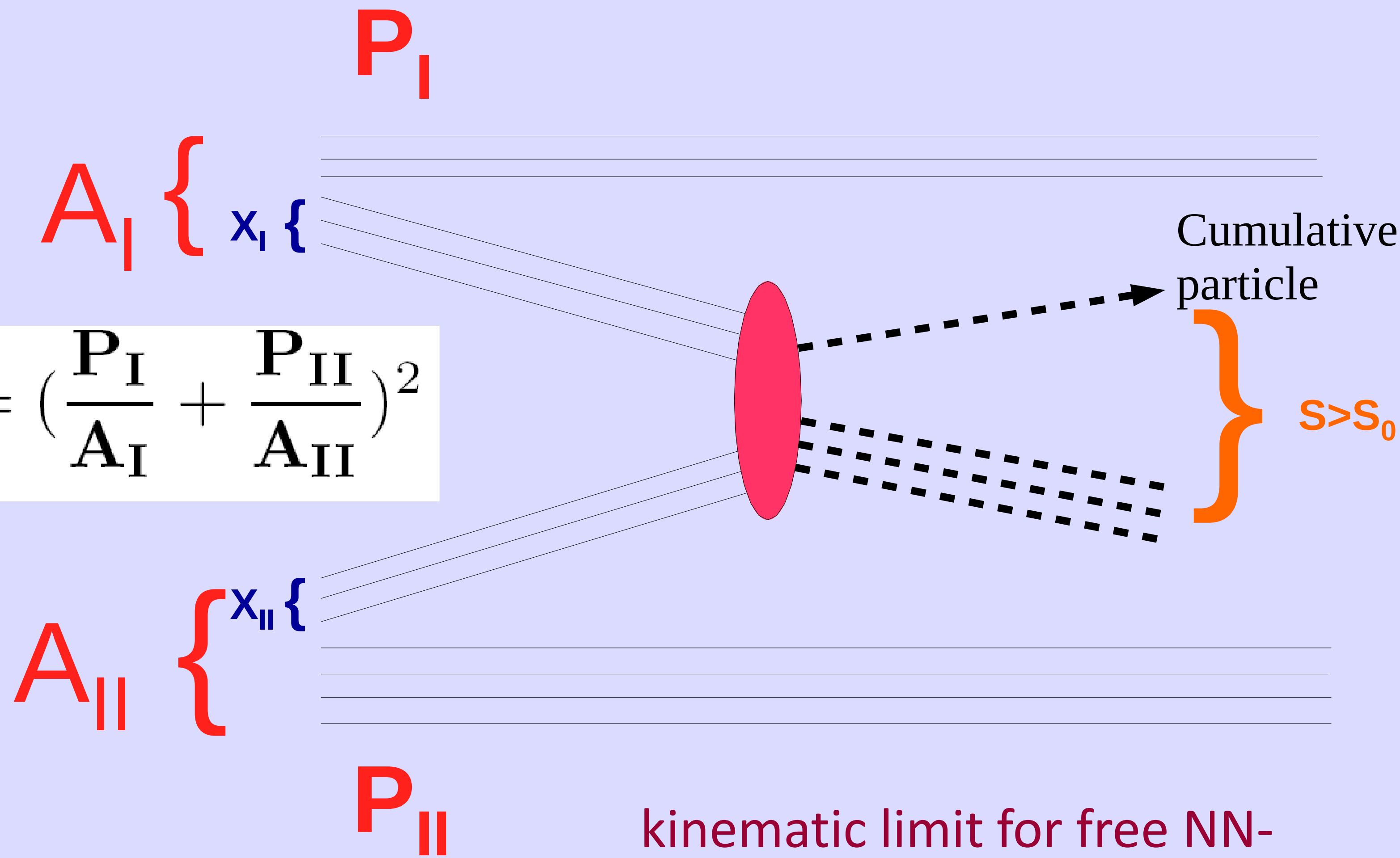
Цель настоящей заметки – рассмотреть этот вопрос и сделать определенные предсказания.

Обычно на вопрос о возможности передачи большой энергии составным ядром отдельному (например, сво–

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

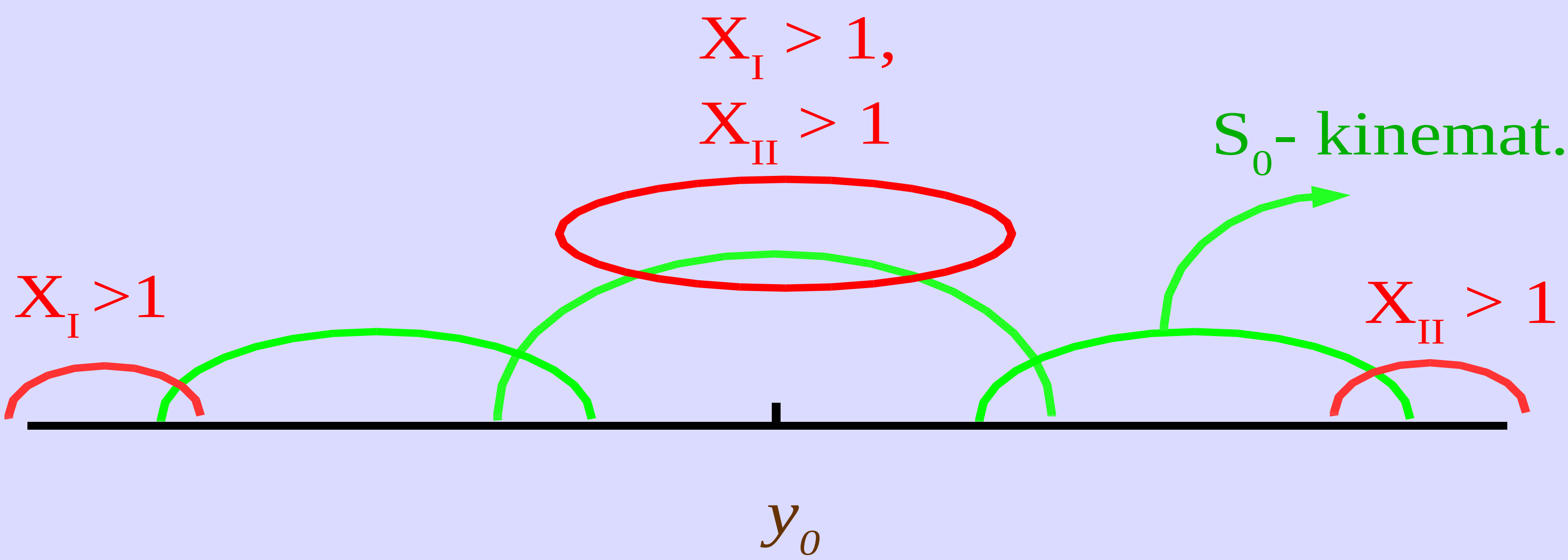
Quark-parton model

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



$$s_0 = \left(\frac{\mathbf{P_I}}{\mathbf{A_I}} + \frac{\mathbf{P_{II}}}{\mathbf{A_{II}}}\right)^2$$

kinematic limit for free NN-interaction



Cumulative processes:

$$\left.\begin{array}{l} 1)\ X_I \le 1 \text{ and } X_{II} > 1 \\ 2)\ X_{II} \le 1 \text{ and } X_I > 1 \end{array}\right\} \text{Fragmentation regions}$$

3) $X_I > 1$ and $X_{II} > 1$ Central region

A.V. Efremov (1976) Parton description

A + B → C + X

$$\varepsilon \frac{d^3\sigma}{d^3p} = \int dx dy dz F_B(y) F_A(x) G_C(z) v(xys, t\frac{x}{z}, u\frac{y}{z})$$

$X_{||}$ $X_{|}$