

“Холодная сверхплотная барионная материя в $p\bar{p}ar-p$ и $p\bar{p}ar-A$ взаимодействиях на ПАНДА”

S.S. Shimanskiy (JINR, LHEP)

Воспоминания об академике Л.А. Арцимовиче Москва, "Наука", 1981

стр.9

"Сейчас уже накопился большой опыт в международном соревновании по основным направлениям физической науки и выяснилось, при каких условиях можно рассчитывать на почетную долю в мировом производстве первоклассной научной информации. **Главная заповедь в этом деле - не идти вслед за сильным соперником по избранному им пути. На узкой дороге трудно обойти машину, идущую впереди. Нужно самим выбирать свой собственный путь - только так можно добиться успеха.**

Для талантливых людей на нетронутых землях науки открывается сразу много разных путей.

... Если вы идете вслед за кем-нибудь, пусть даже почти по пятам, то радость первых открытий вам не удастся испытать, она будет уделом тех, кто хоть немного, но впереди."

Л.А. Арцимович

СОДЕРЖАНИЕ

1. Фазовая диаграмма состояний ядерной материи (современные представления) и холодная сверхплотная барионная материя(ХСпБМ).
2. Открытие и исследование свойств ХСпБМ.
3. High p_T probes and SPIN data
4. Уникальные возможности PANDA
4. Область $p_T \sim 2$ ГэВ/с аномалии

RHIC Physics: 3 Lectures*

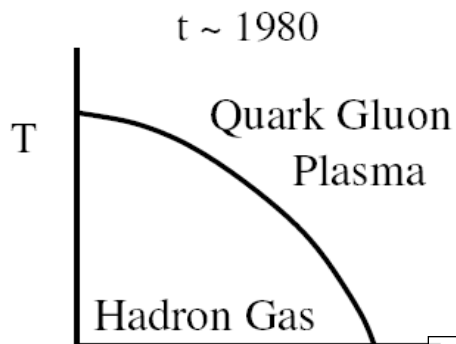
Larry McLerran

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

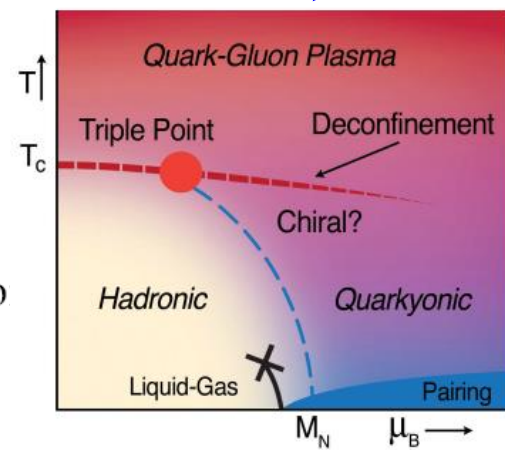
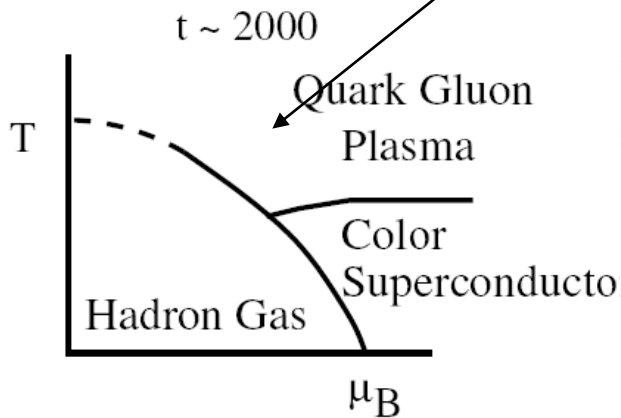
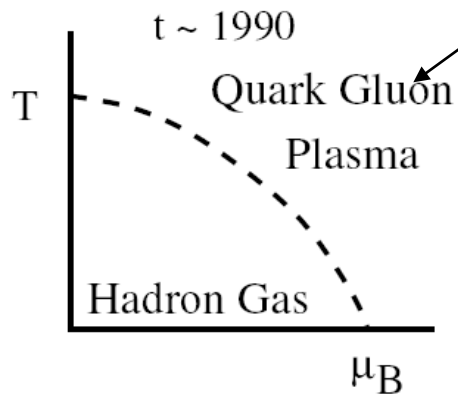


Critical Temperature 150 - 200 MeV ($\mu_B = 0$)
Critical Density 1/2-2 Baryons/Fm³ ($T = 0$)

Nuclear Physics A 837 (2010) 65-86

Nuclotron-SPS Time (CERN)

RHIC Time(BNL)



Magdeburg hemispheres 1656



Edward Shuryak

ICPAQGP, Kolkata, India,
February 8-12, 2005 8-
12, 2005

- We cannot pump the QCD vacuum out, but we can pump in something else, namely the Quark-Gluon Plasma –arguments from 1970's
- QGP was looked at as a much simpler thing, to be described by pQCD. We now see it is also quite complicated matter, sQGP...

Proceedings of the DPF-2009 Conference, Detroit, MI, July 27-31, 2009

Theoretical Concepts for Ultra-Relativistic Heavy Ion Collisions

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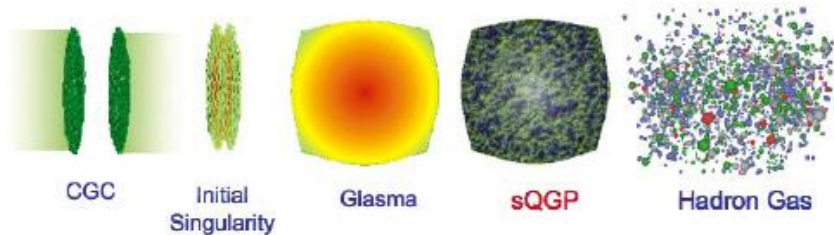


Figure 1: Ultra-relativistic nuclear collisions and various forms of high energy density matter.

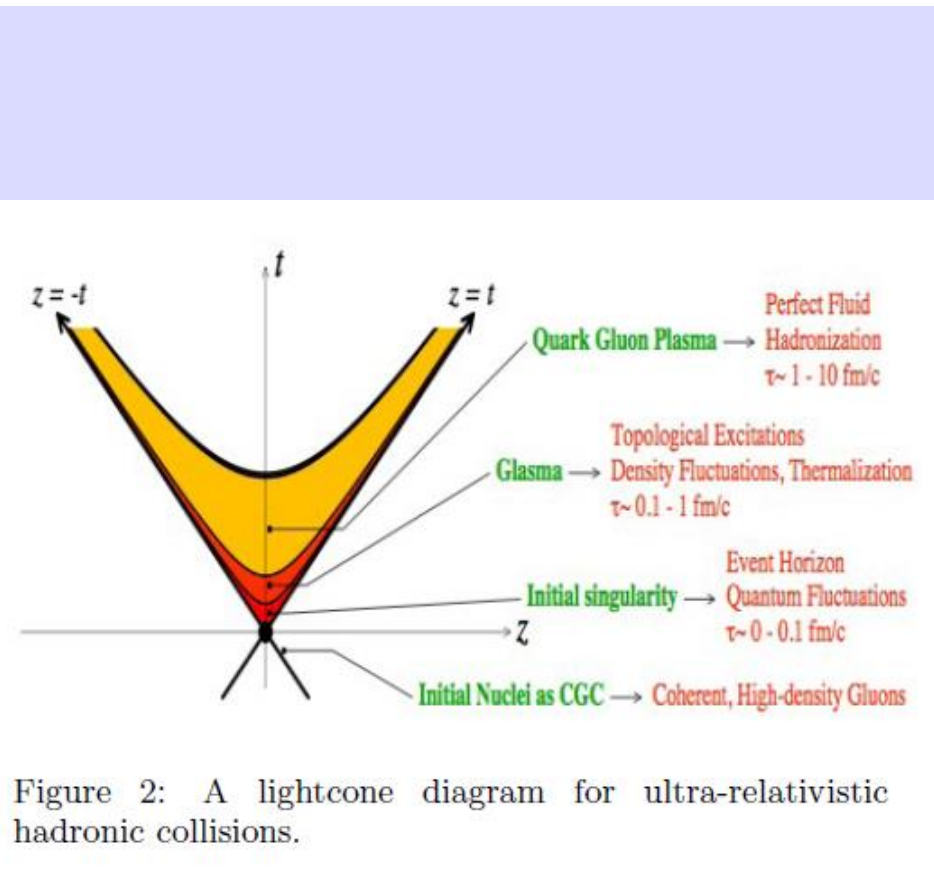


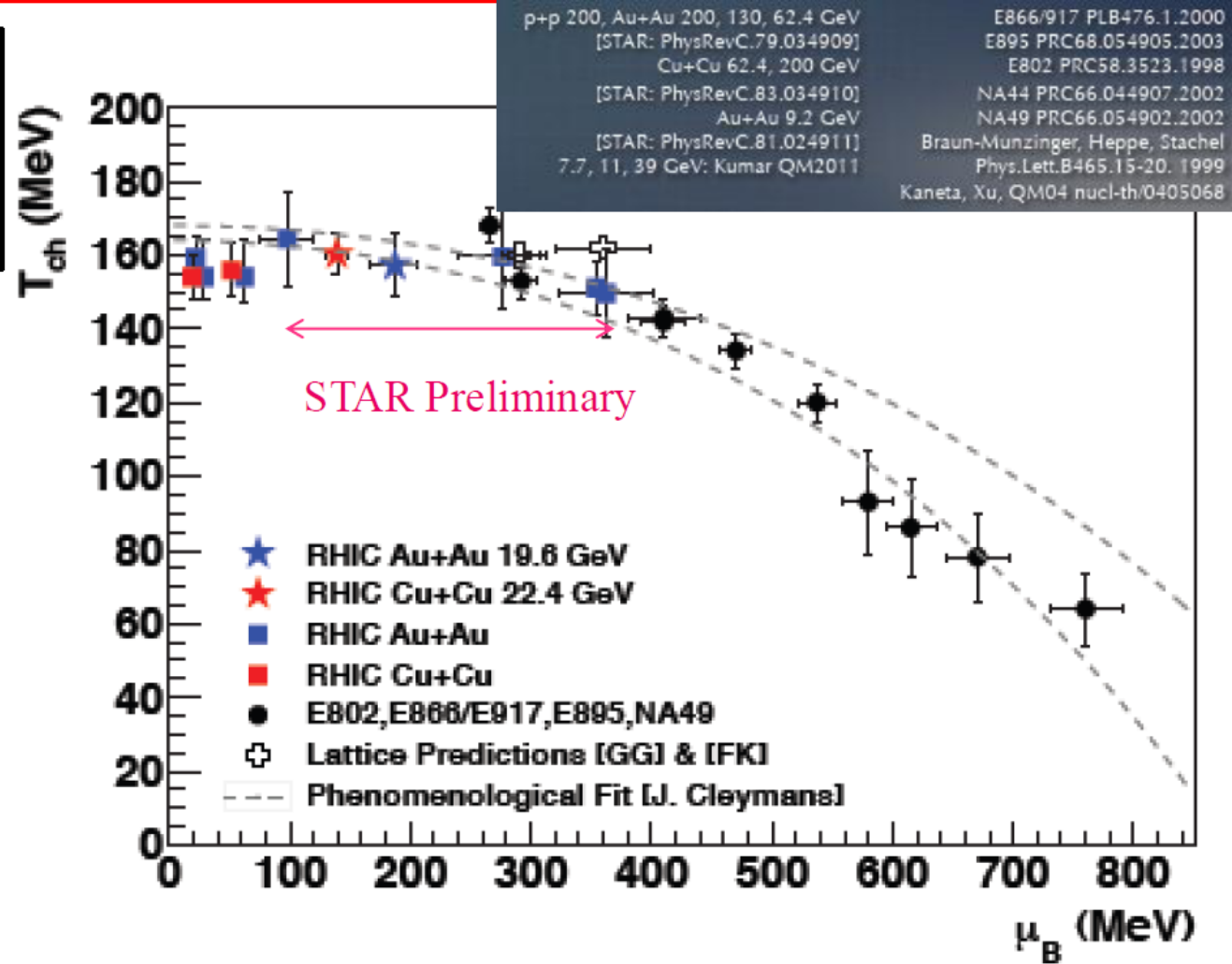
Figure 2: A lightcone diagram for ultra-relativistic hadronic collisions.

Where are We on the Phase Diagram

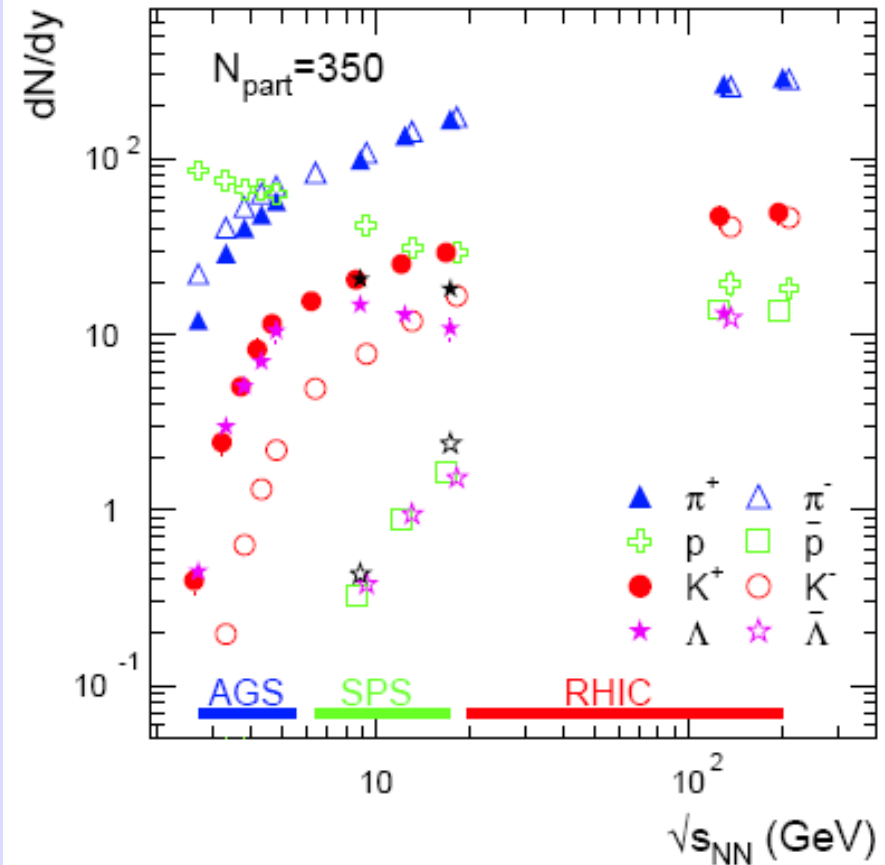
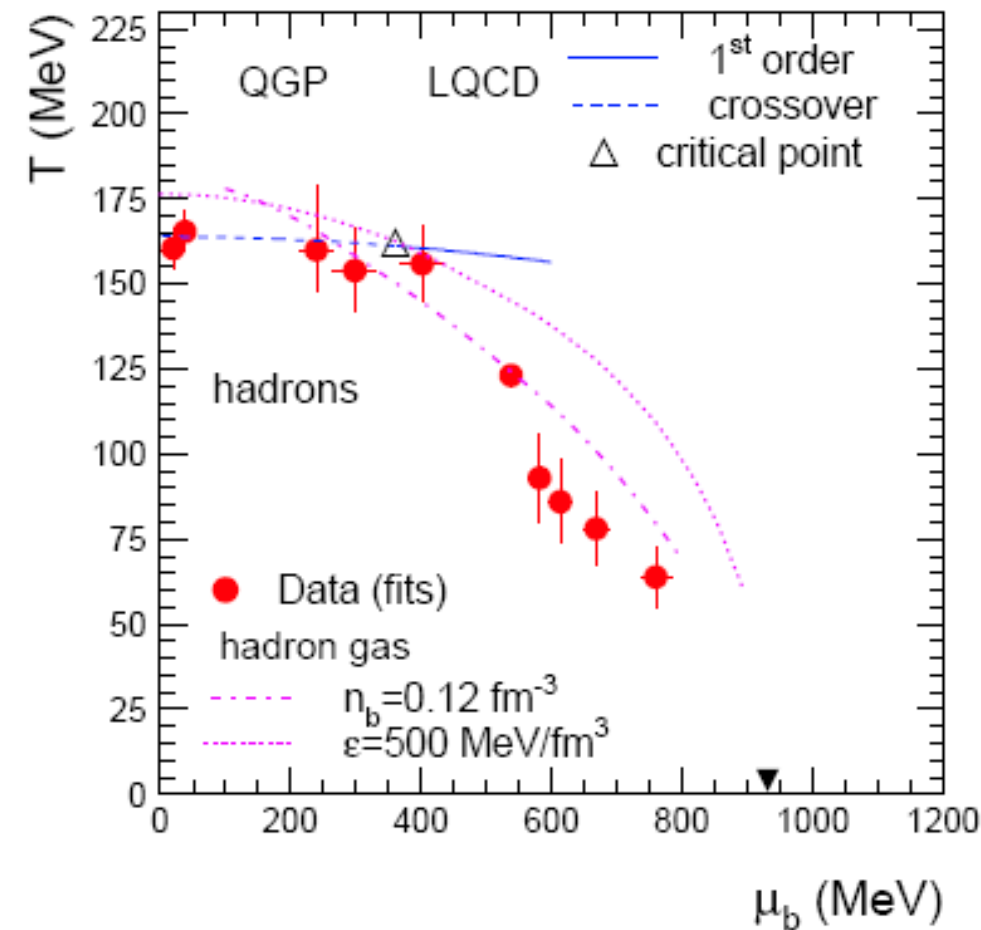


$$\frac{d^6 N}{dx^3 dp^3} = g \ln \left(\frac{1}{e^{\frac{E-\mu}{T}} \pm 1} \right)$$

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

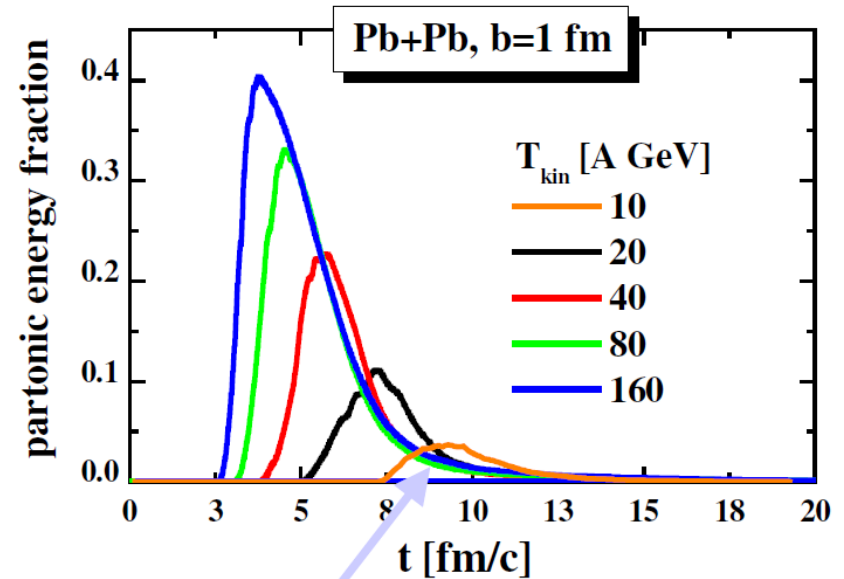
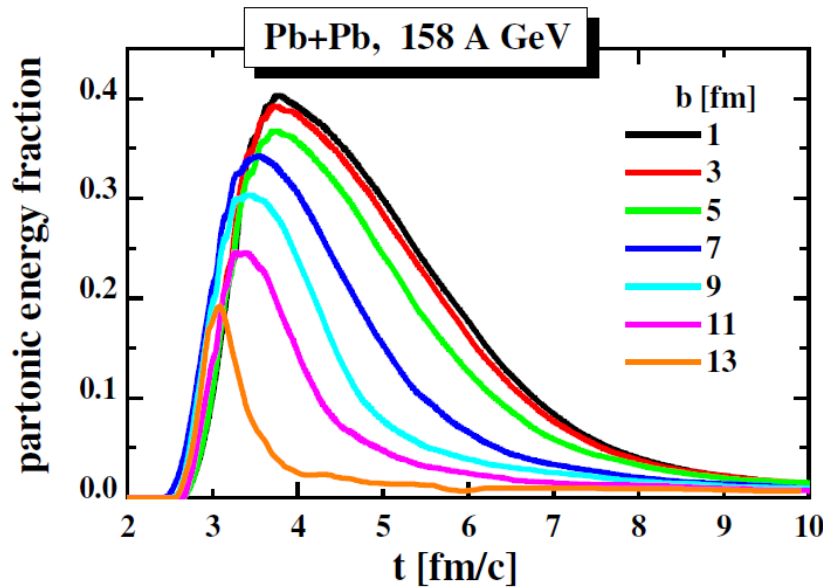


O. Mall SQM2011



Partonic phase at SPS/FAIR/NICA energies

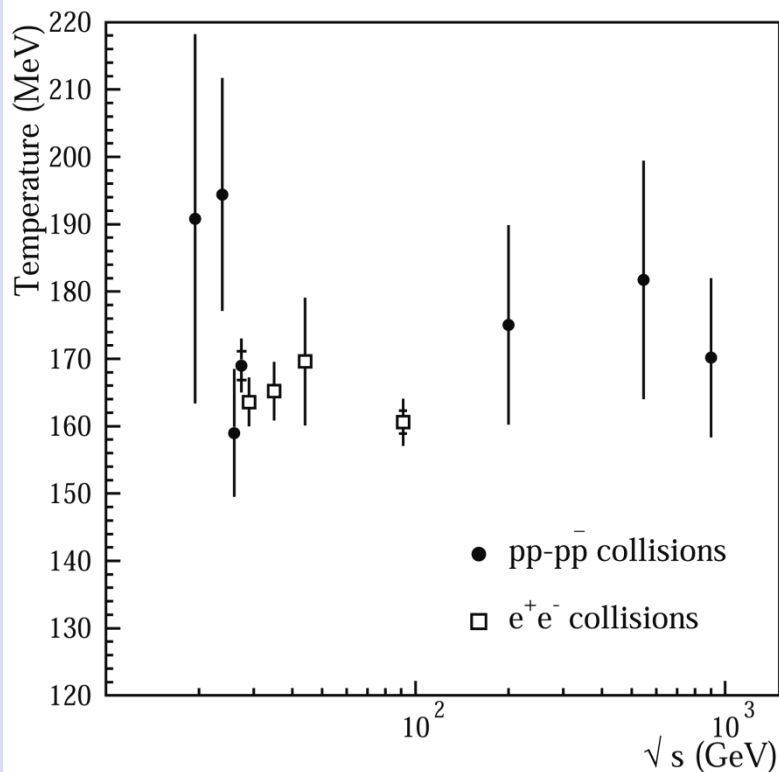
partonic energy fraction vs centrality and energy



Dramatic decrease of partonic phase with decreasing energy and centrality

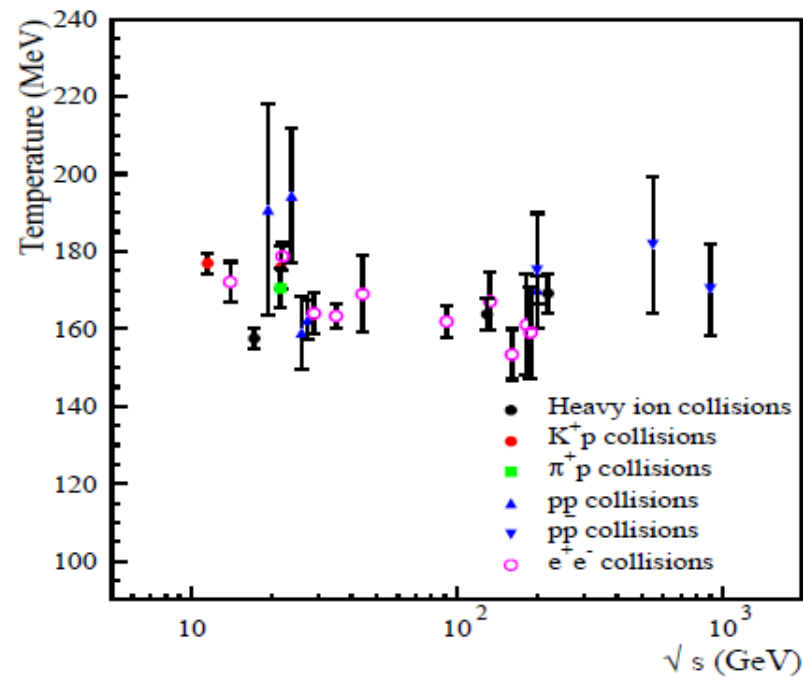
Thermalization in Elementary Collisions ?

Beccatini, Heinz,
Z.Phys. C76 (1997) 269



Helmut Satz

arXiv:1207.0341v1 [hep-ph] 2 Jul 2012



- **$T \approx 170$ MeV** (good old Hagedorn temperature)

- **T_{ch} does not (or only weakly) depends on \sqrt{s}**

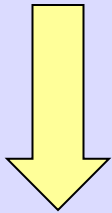
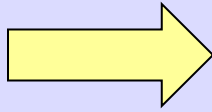
- **Universal hadronization mechanism at critical values ?**

Discovery and Investigation with Different Probes

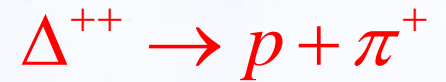
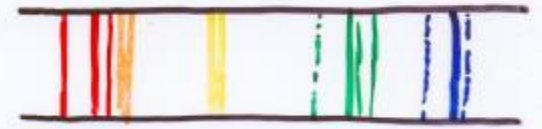
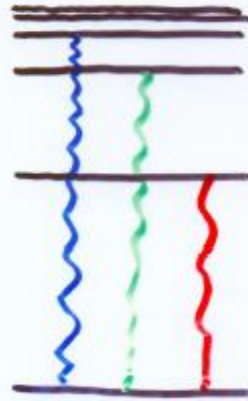
F. Close

Structure of Matter

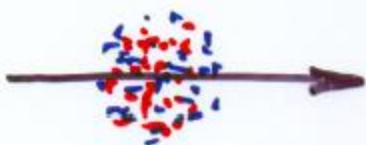
Two ways that structure is revealed:



1. SPECTRA

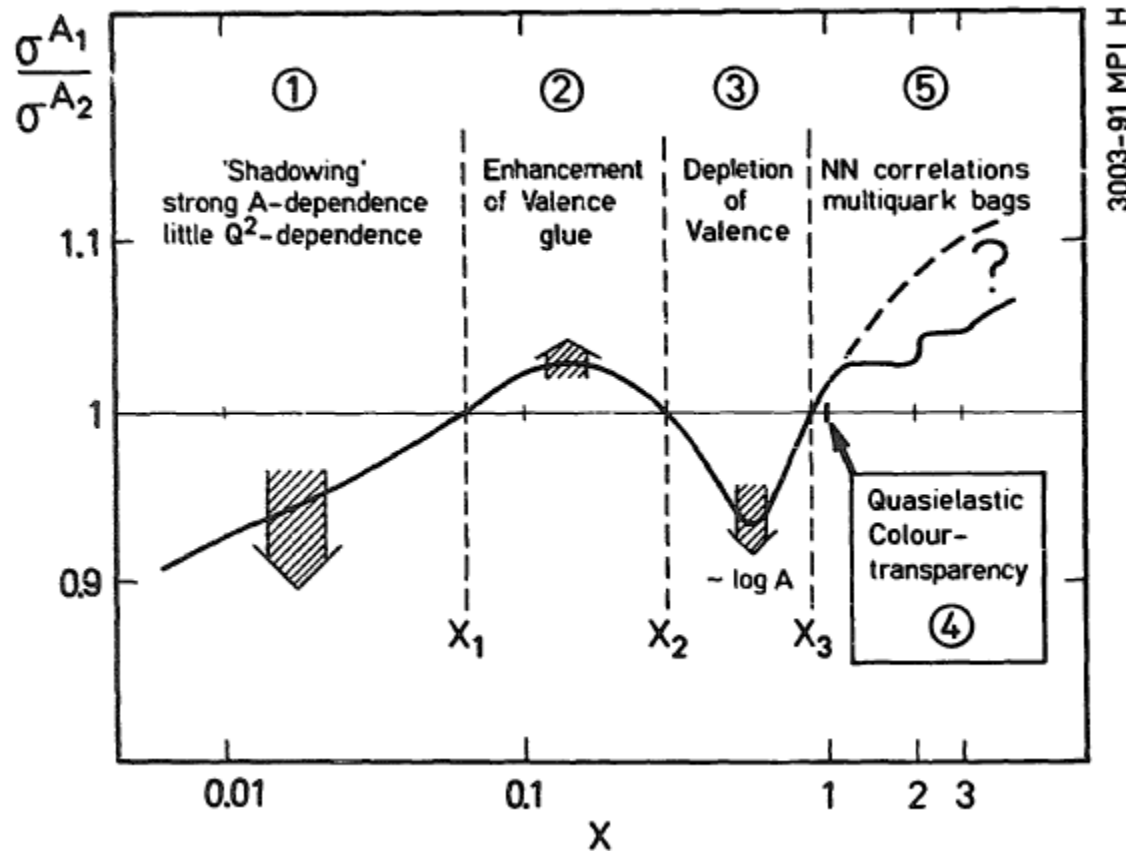


2. SCATTERING FROM "HARD" CENTRES



True from atoms to particles.....

DIS with Leptons



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.

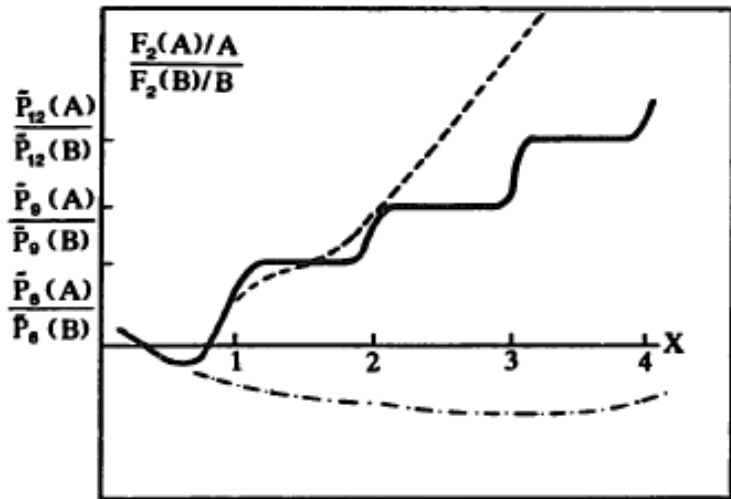


Figure 5. Theoretical predictions for nuclear structure functions at $x > 1$

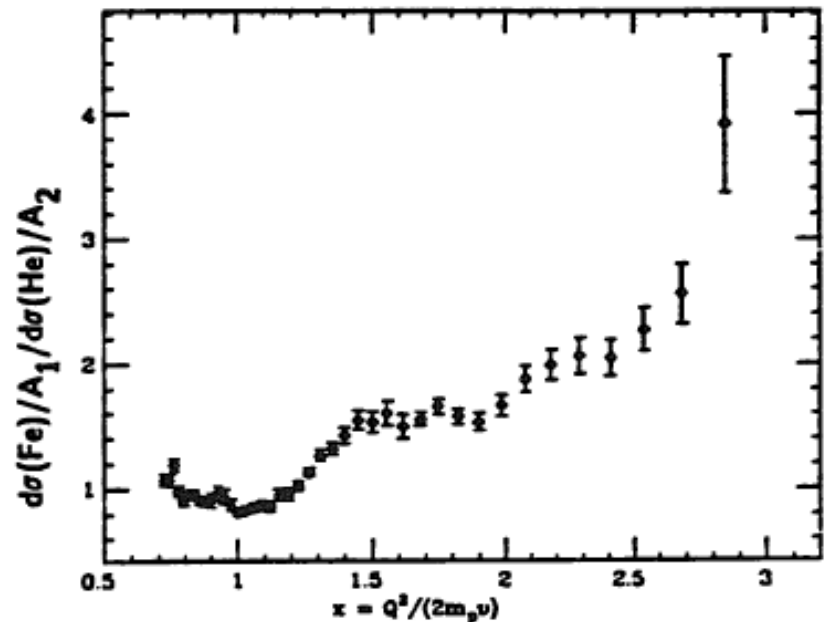


Figure 6. Preliminary results for σ^{Fe}/σ^{He} from NE-2 at SLAC

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

Nuclear structure functions at $x > 1$

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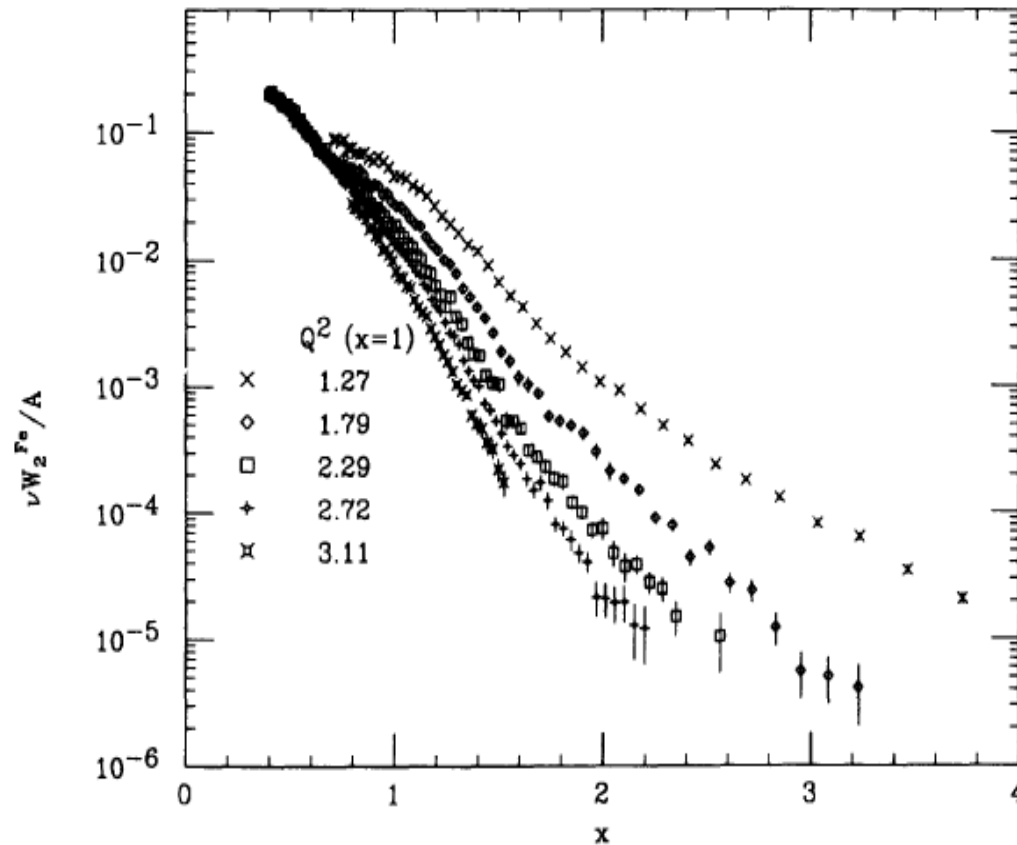


FIG. 1. Measured structure function per nucleon for Fe vs x .
 The Q^2 value at $x = 1$ is also listed for the different kinematics.

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

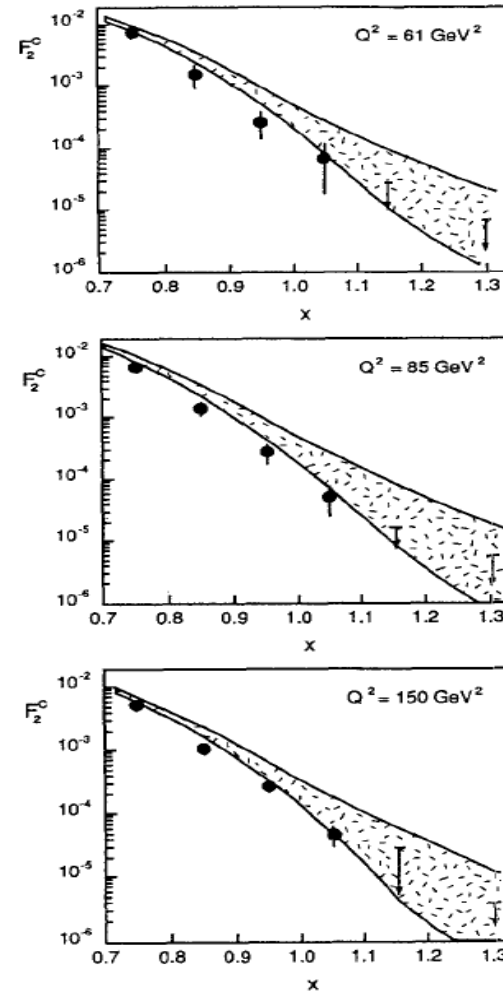


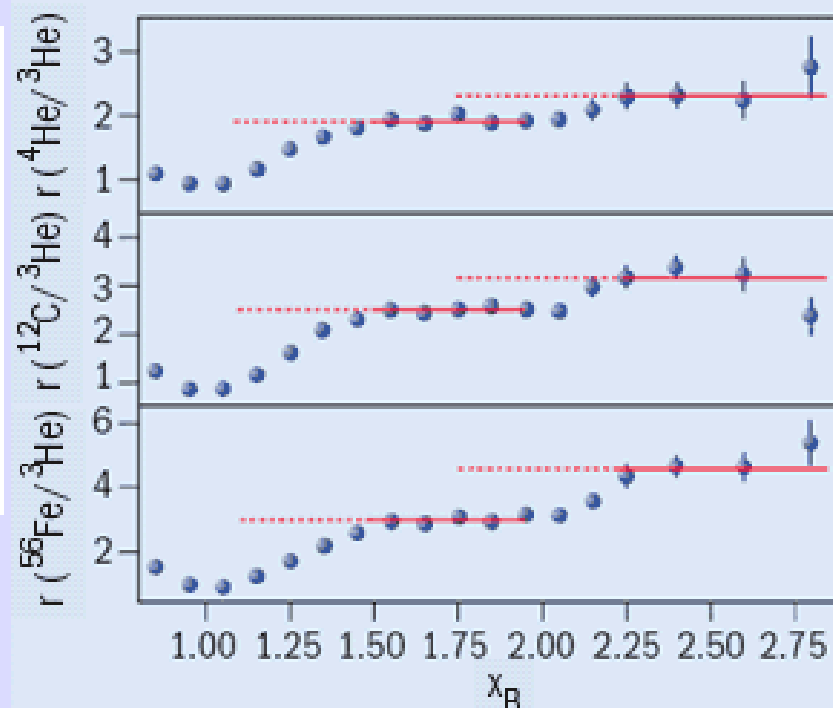
Fig. 7. The nuclear structure function $F_2^C(x)$ as a function of x , at three different values of Q^2 . The hatched regions show the range of predictions of [26]

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

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$$r(A, {}^3\text{He}) = \frac{A(2\sigma_{ep} + \sigma_{en})}{3(Z\sigma_{ep} + N\sigma_{en})} \frac{3\mathcal{Y}(A)}{A\mathcal{Y}({}^3\text{He})} C_{\text{rad}}^A, \quad (2)$$

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_{rad}^A is the ratio of the radiative correction factors for A and ${}^3\text{He}$ ($C_{\text{rad}}^A = 0.95$ and 0.92 for ${}^{12}\text{C}$ and ${}^{56}\text{Fe}$ 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 ${}^4\text{He}$ and 1.18 ± 0.02 for ${}^{56}\text{Fe}$. Fig. 1 shows the resulting ratios integrated over $1.4 < Q^2 < 2.6 \text{ GeV}^2$.



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

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

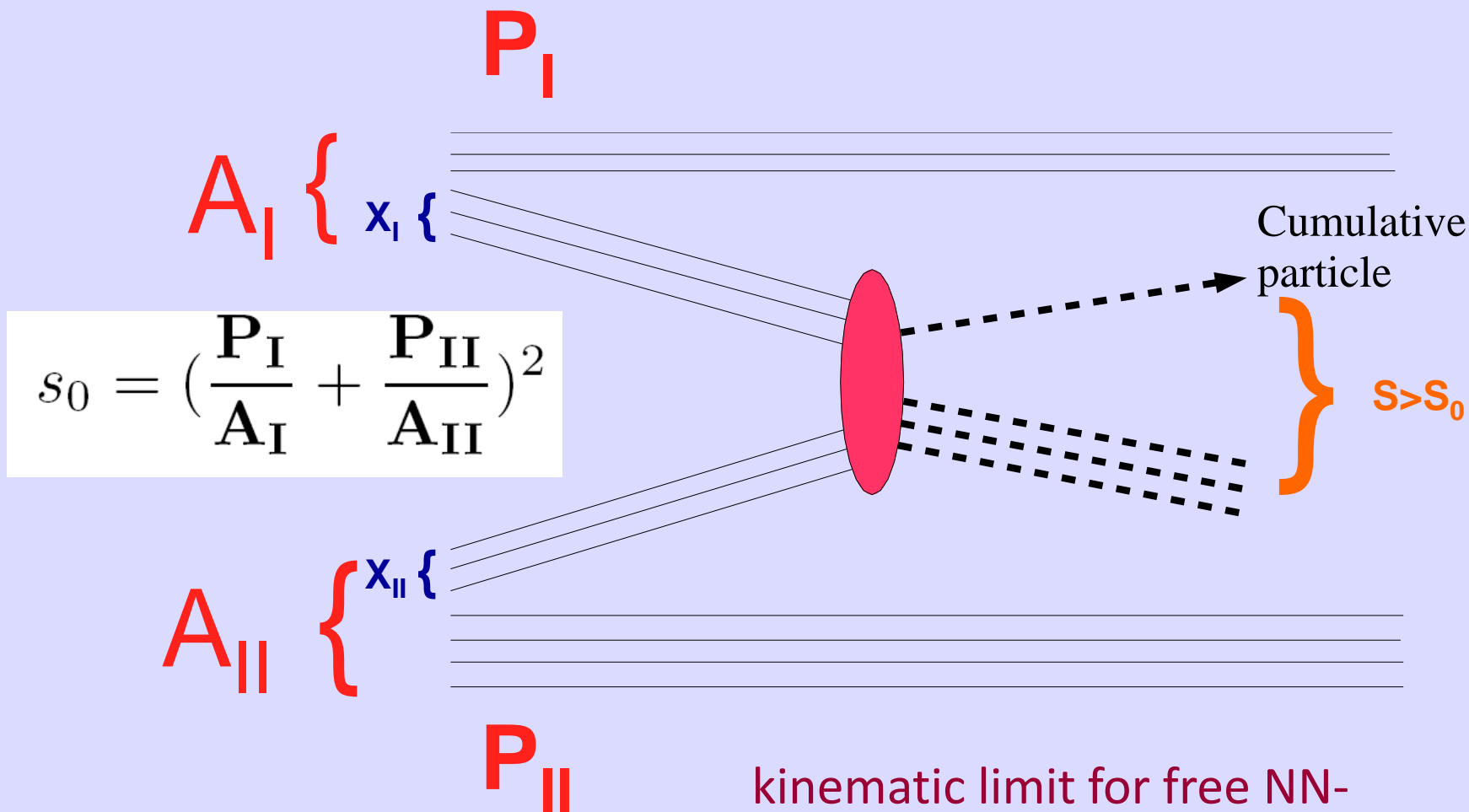
$$\begin{aligned}
 & a_{pp}(^{12}\text{C}) \approx 4 \pm 2 \% \\
 & a_{2N}(^{12}\text{C}) \approx 20 \pm 0.2 \pm 4.1 \% \quad \longrightarrow \quad a_{pn}(^{12}\text{C}) \approx 12 \pm 4 \% \\
 & a_{nn}(^{12}\text{C}) \approx 4 \pm 2 \%
 \end{aligned}$$

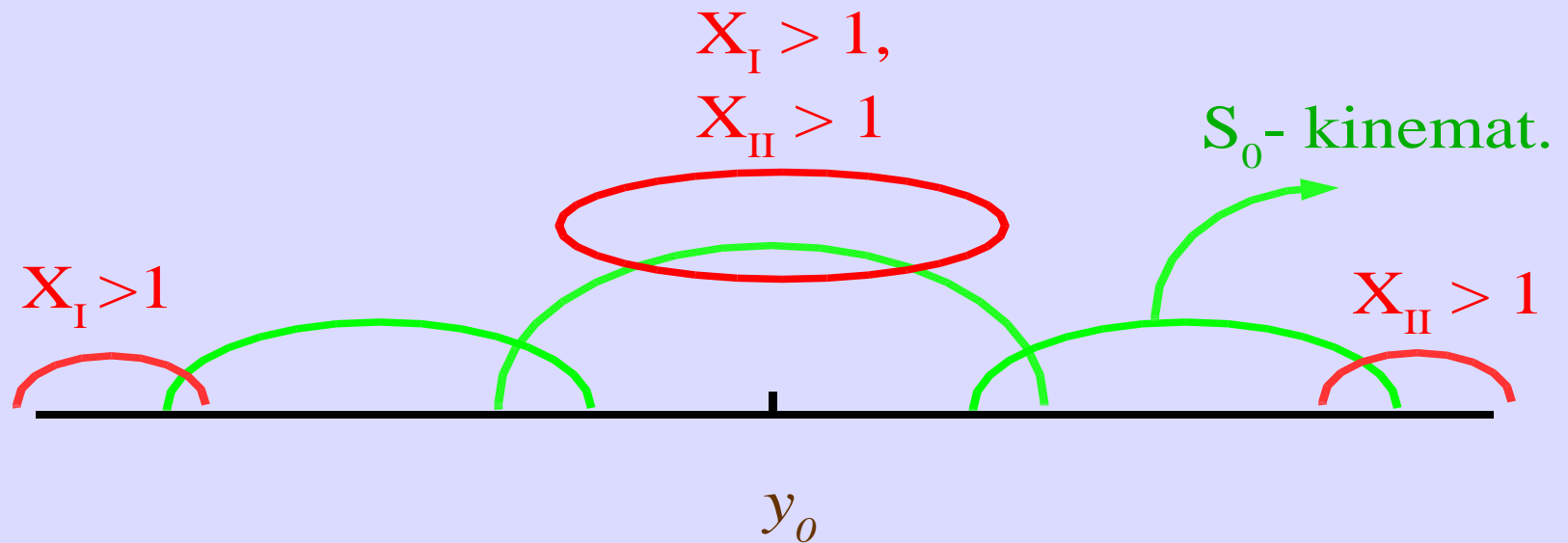
SPECTRA

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

Quark-parton model

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



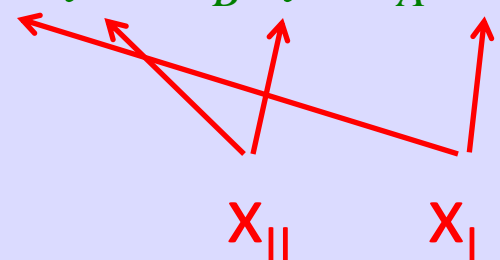


Cumulative processes:

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

A.V. Efremov (1976) Parton description



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


The diagram shows three red arrows originating from the variables x , y , and z in the integrand. The arrow from x points to the label X_{\perp} . The arrow from y points to the label X_{\parallel} . The arrow from z points to the label X_{\perp} .

TEOPVIB

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.

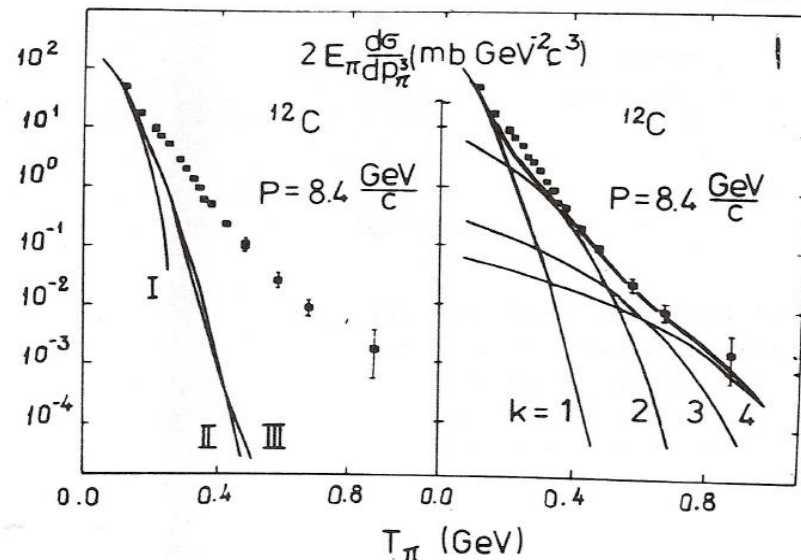


Fig. 1. (a) Calculations of the invariant pion production cross section for ^{12}C : I – for the free proton target; II – with fermi motion; III – the relativization effect. (b) The contributions of separate fluctuons with mass $M_k = km_p$ where k is the order of cumulativity.

Fluctons Probability inside nuclei

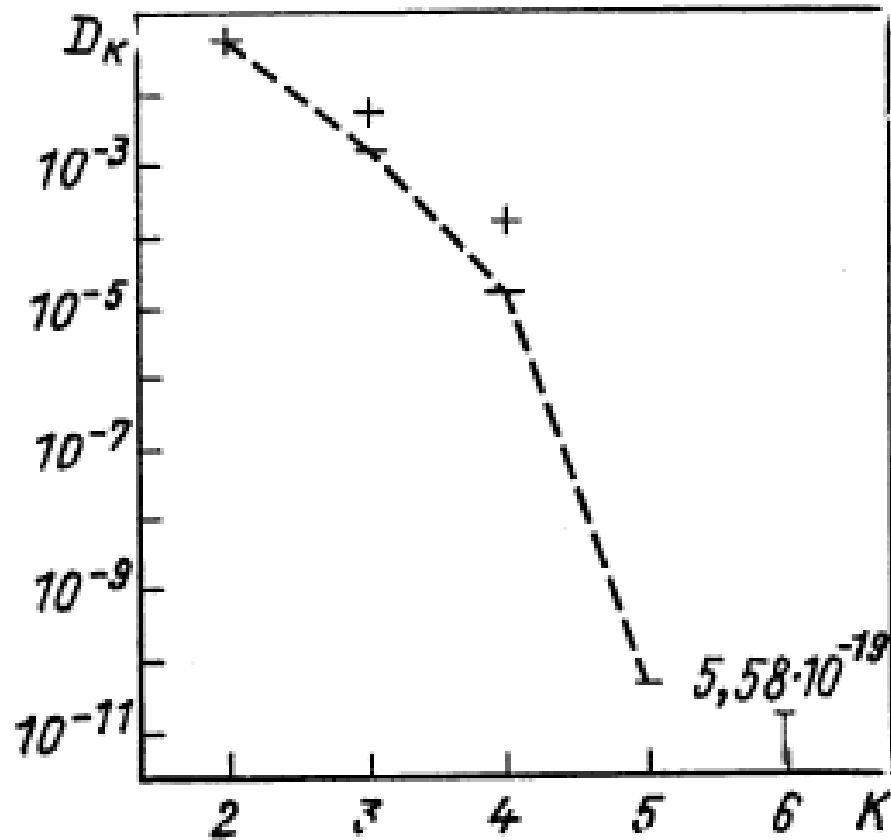


Рис. 19. Вероятность существования флуктонов с k нуклонами в ядрах

A - dependence (1974-...)

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

$$\varepsilon \frac{d\sigma}{dp} (p + A \rightarrow B) \sim \begin{cases} A^{5/3} - \text{for} _ d \\ A^2 - \text{for} _ t \end{cases}$$

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

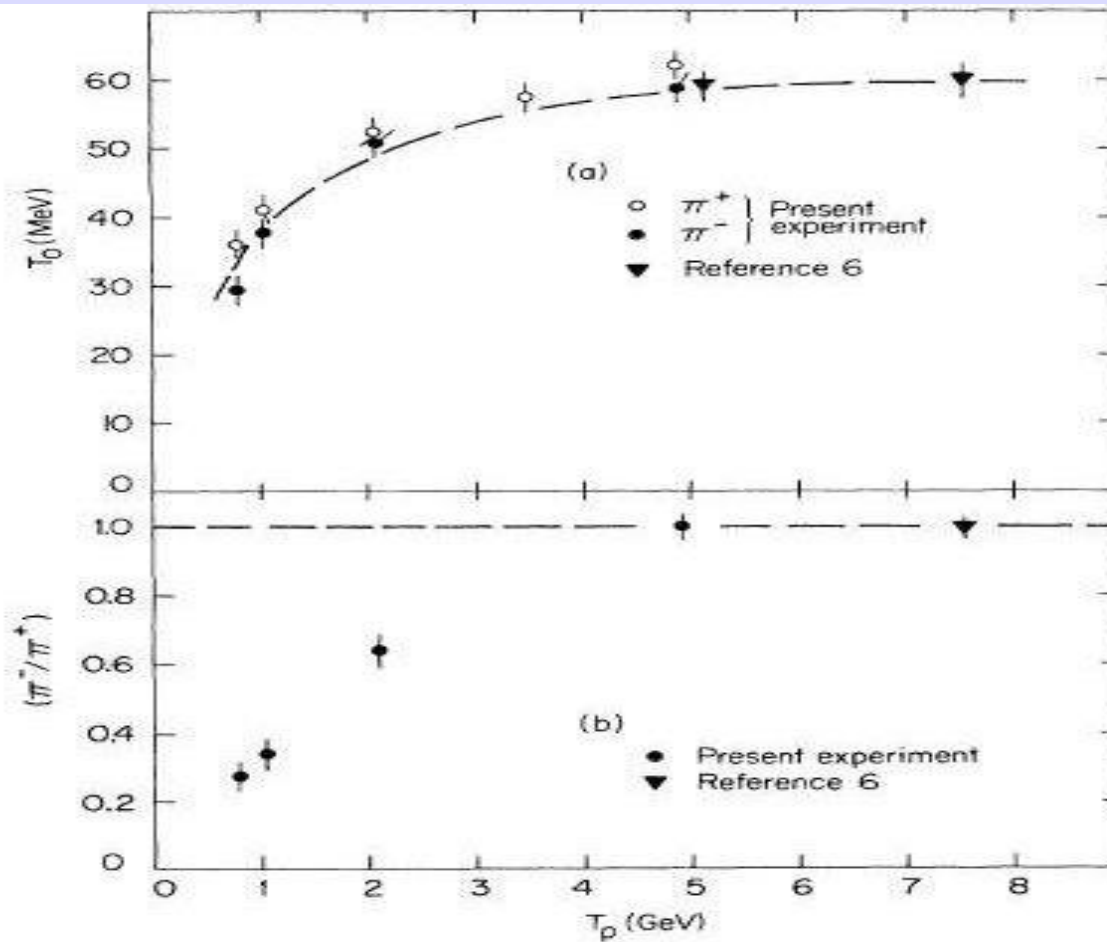
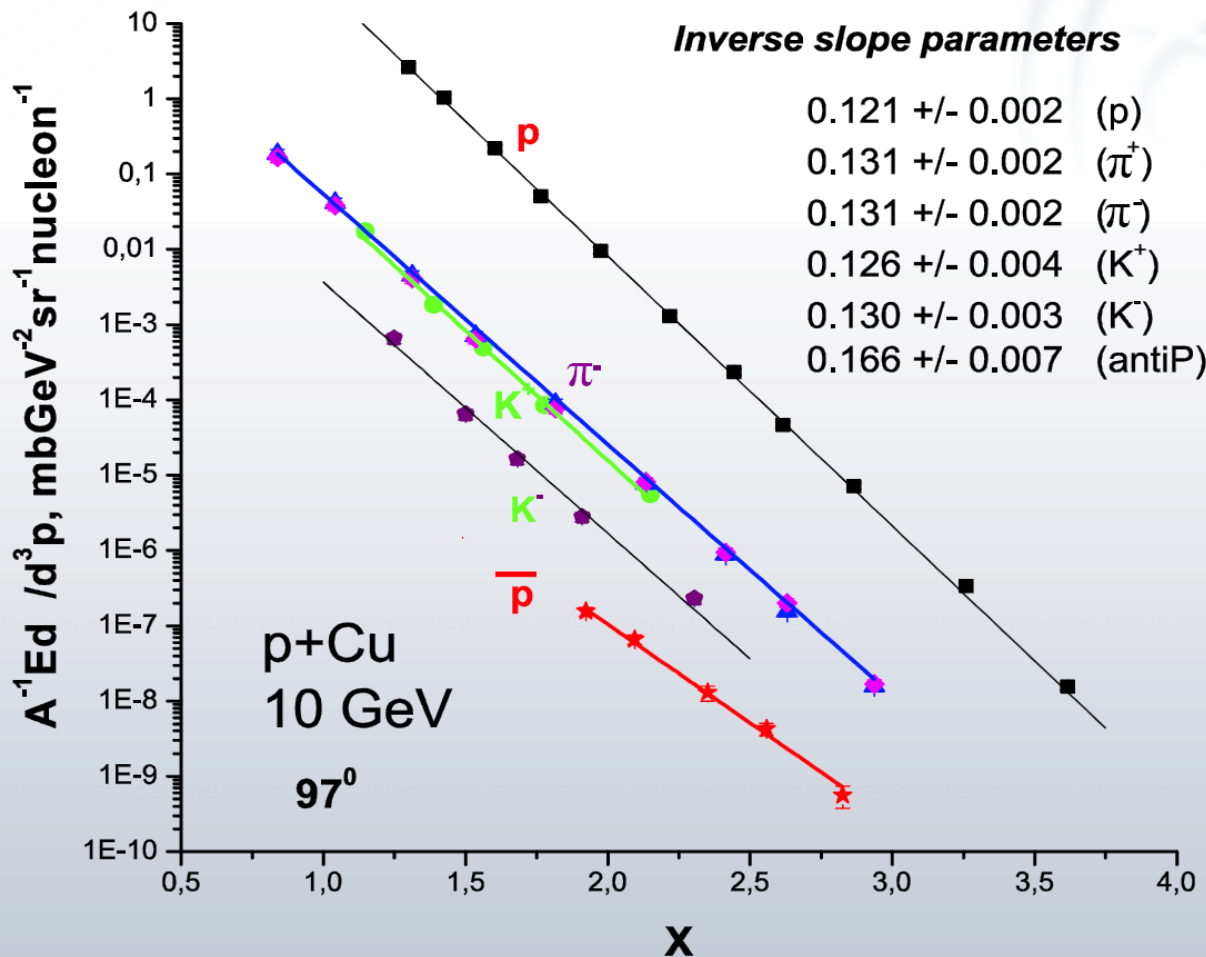


FIG. 1. Energy dependence of (a) T_0 parameter for pions, and (b) the π^-/π^+ ratio at 180° obtained by integrating each spectra up to 100 MeV for p -Cu collisions from 0.8 to 4.89 GeV. The dashed curve in both cases refers to the predictions of the "effective-target" model (Refs. 3 and 4).



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

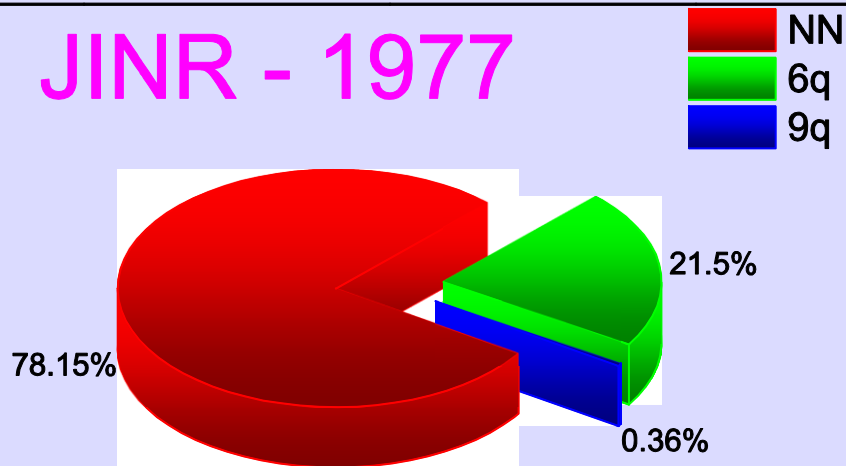
V.V.B., V.K.Lukyanov, A.I.Titov, PLB, 67, 46(1977)

eA - program at JLab

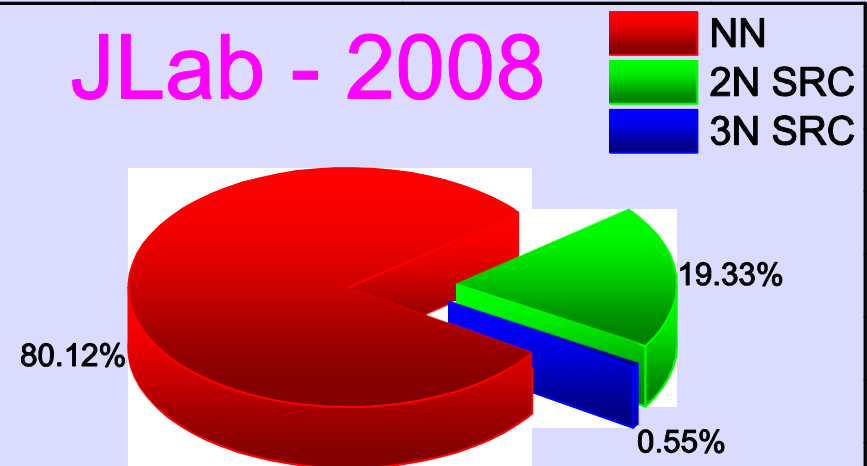
R.Subedi et al., Science 320 (2008) 1476-1478

e-Print: arXiv:0908.1514 [nucl-ex]

JINR - 1977



JLab - 2008



Correlation Measurements

And why high p_T probes?

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

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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 $p_x \sim 0$ 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)

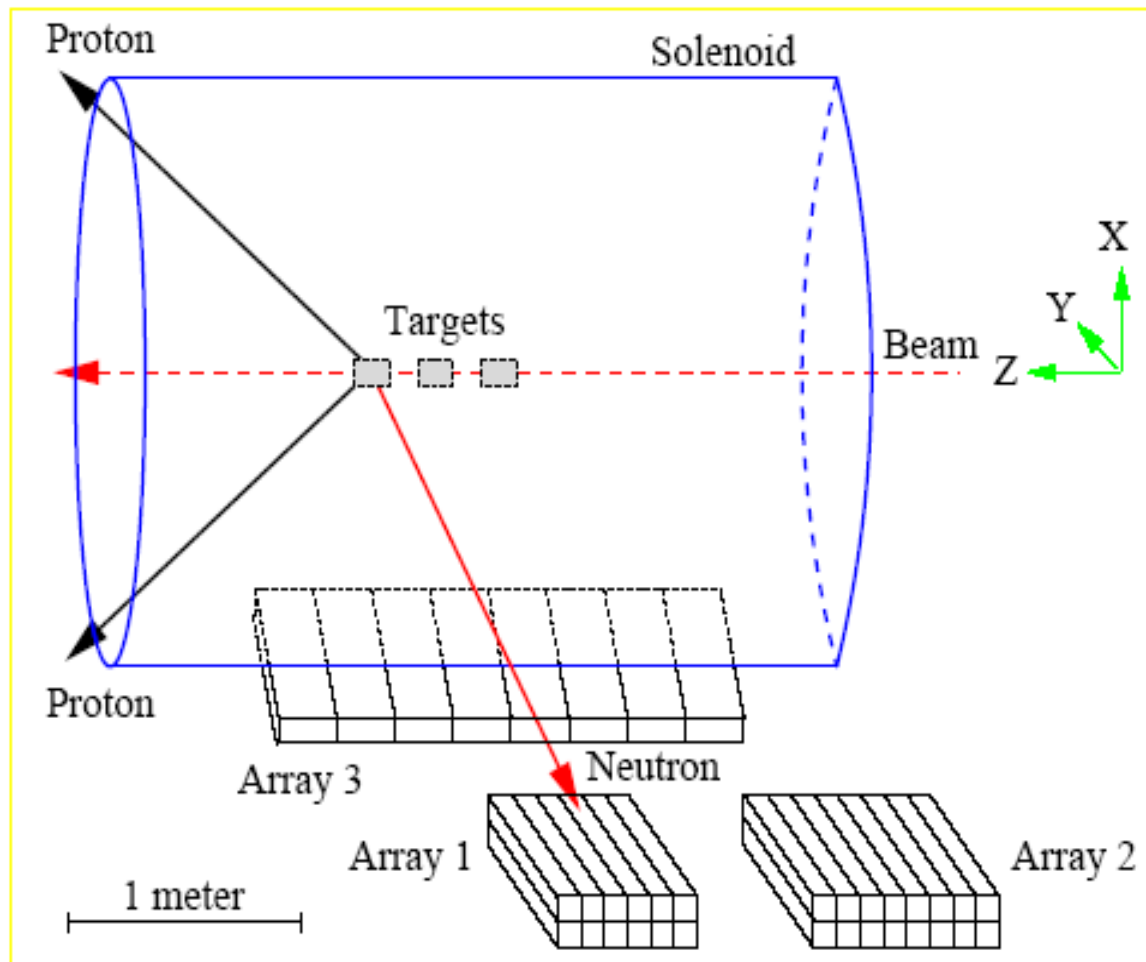


Figure I.3: A schematic view of the EVA solenoid and the neutron counters in the 1998 measurement.

***n-p* Short-Range Correlations from (*p*, 2*p* + *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}
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 I. Navon,² H. Nicholson,⁷ A. Ogawa,⁶ Yu. Panebratsev,⁸ E. Piassetzky,² A. Schetkovsky,^{6,5} S. Shimanskiy,⁸ and
 D. Zhalov⁶

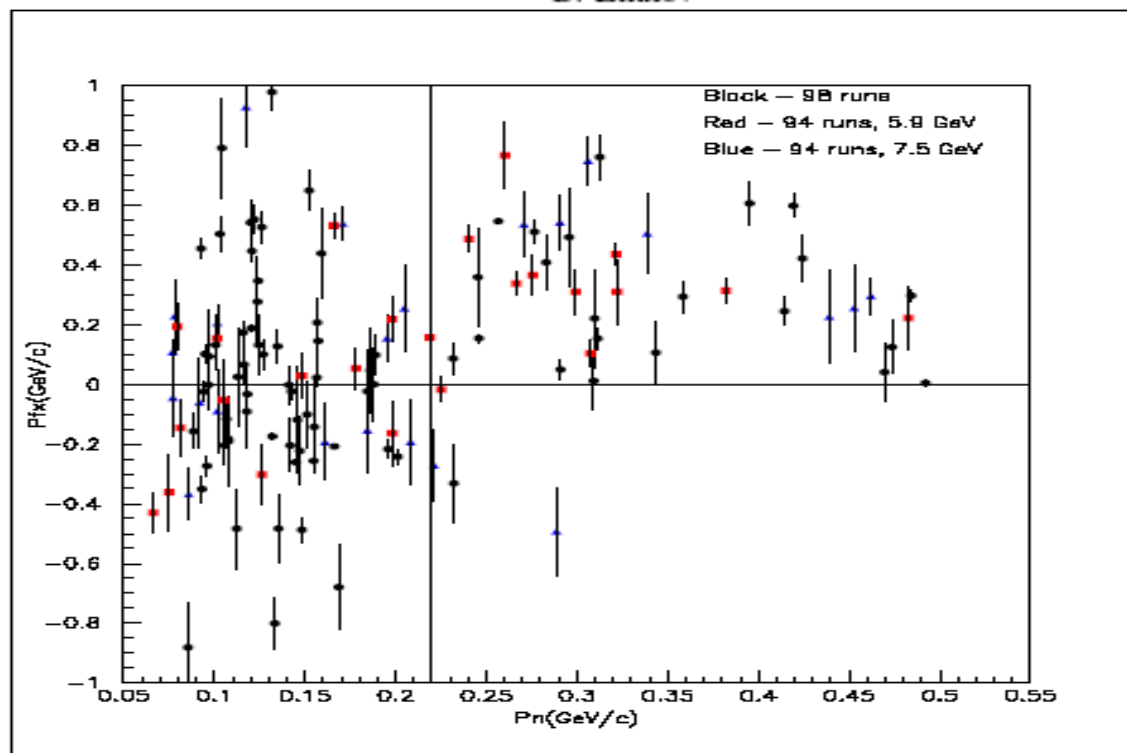


Figure I.5: The vertical component of the target nucleon momentum vs. the total neutron momentum. The positive vertical axis is the upward direction. The events shown are for triple coincidences of the neutron with the two high energy protons emerging from the QE $C(p, 2p)$ reaction. The squares are 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 running period. We associate the events in the upper right corner with NN SRC.

Short-Distance Structure of Nuclei

D W Higinbotham¹, E Piassetzky² and S A Wood¹

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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. ‡

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. Piassetzky,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. Zhu³²

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 ¹²C 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.

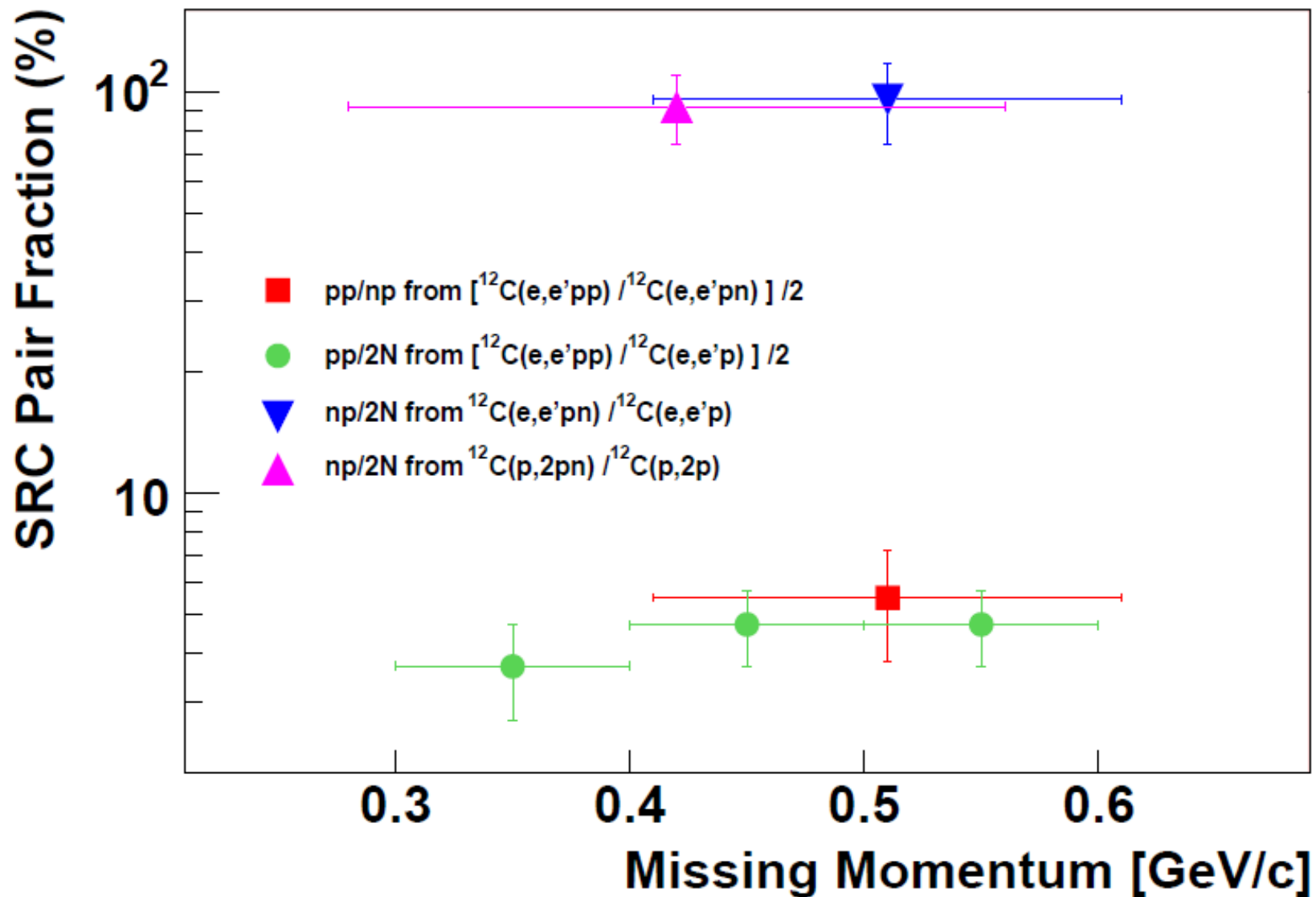
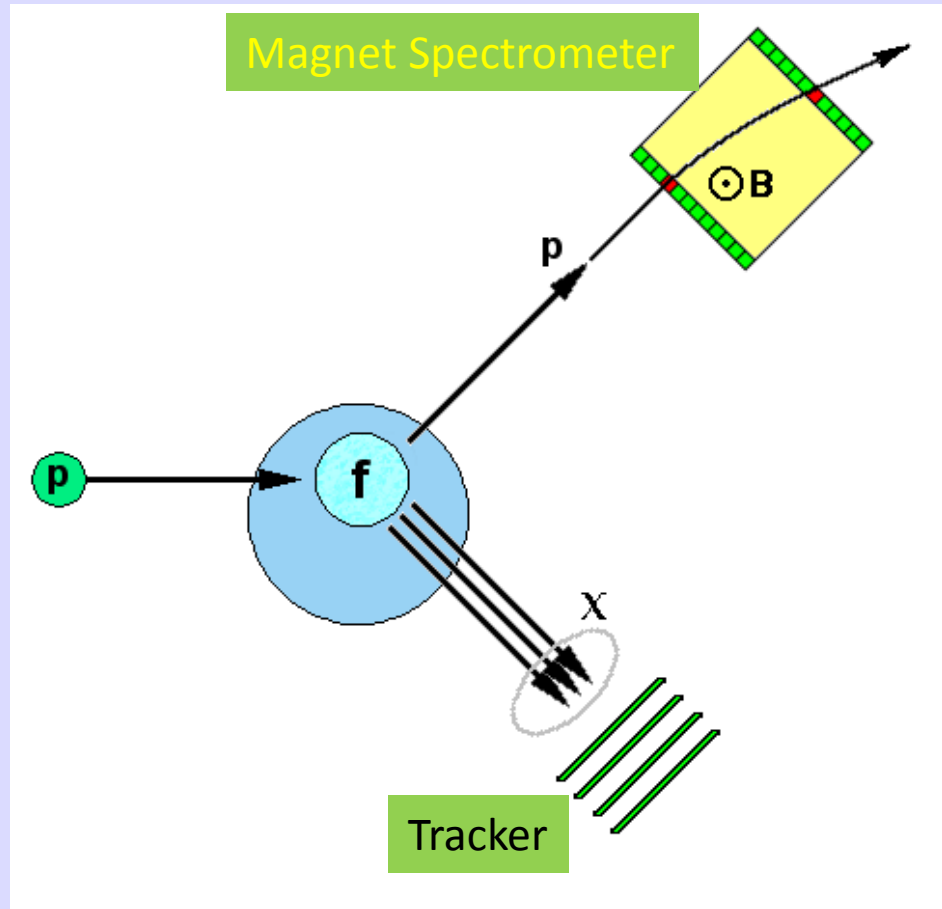


Figure 7. The fractions of correlated pair combinations in carbon as obtained from the $(e, e'pp)$ to $(e, e'pn)$ reactions [48], as well as from previous $(p, 2pn)$ data [45]. From Subedi R *et al.* (Hall A) 2008 *Science* **320** 1476. Reprinted with permission from AAAS.

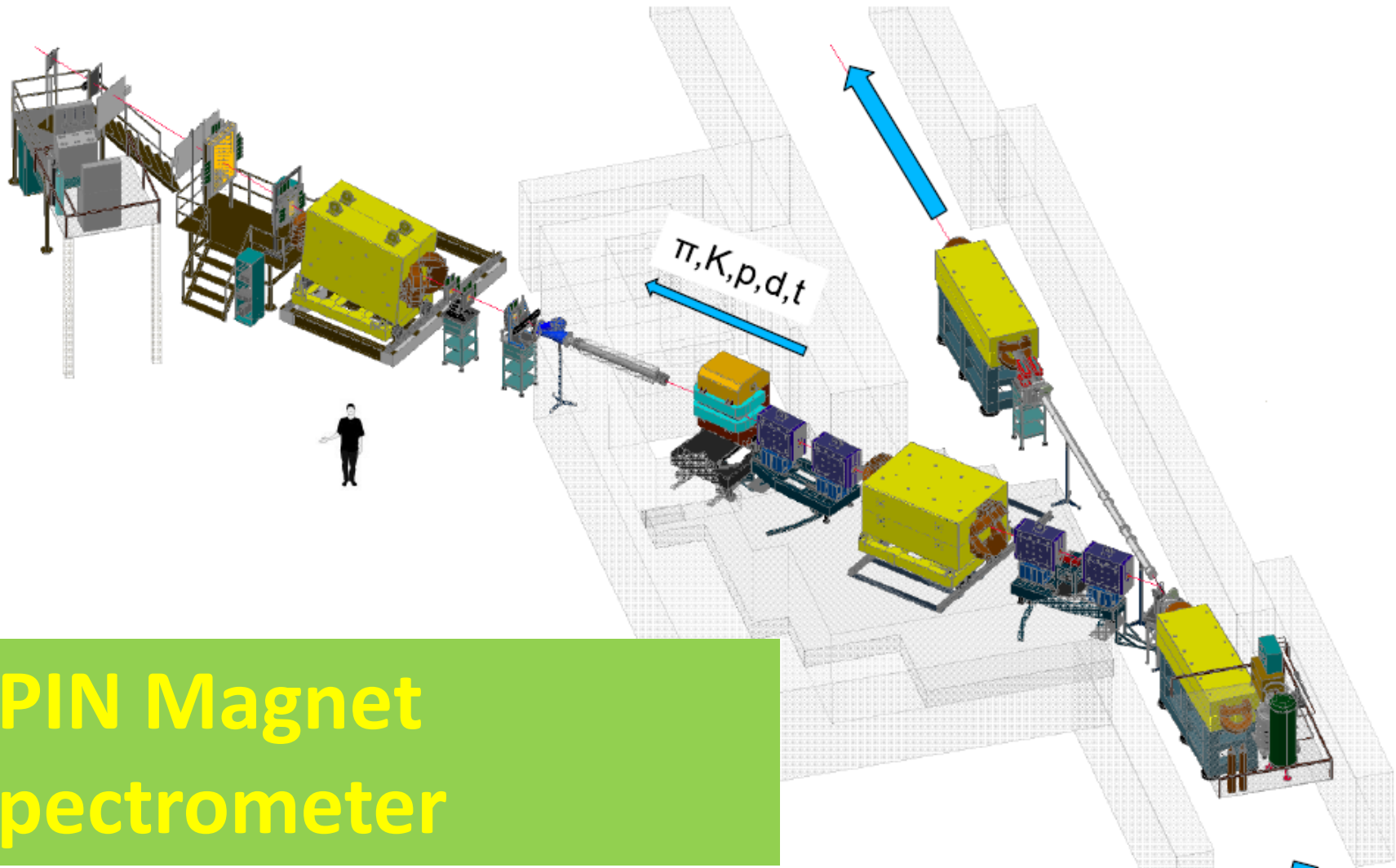
The Correlation Measurements with hadrons

$$pA \rightarrow h + X$$

$$x_T \sim 1$$



SPIN Magnet Spectrometer

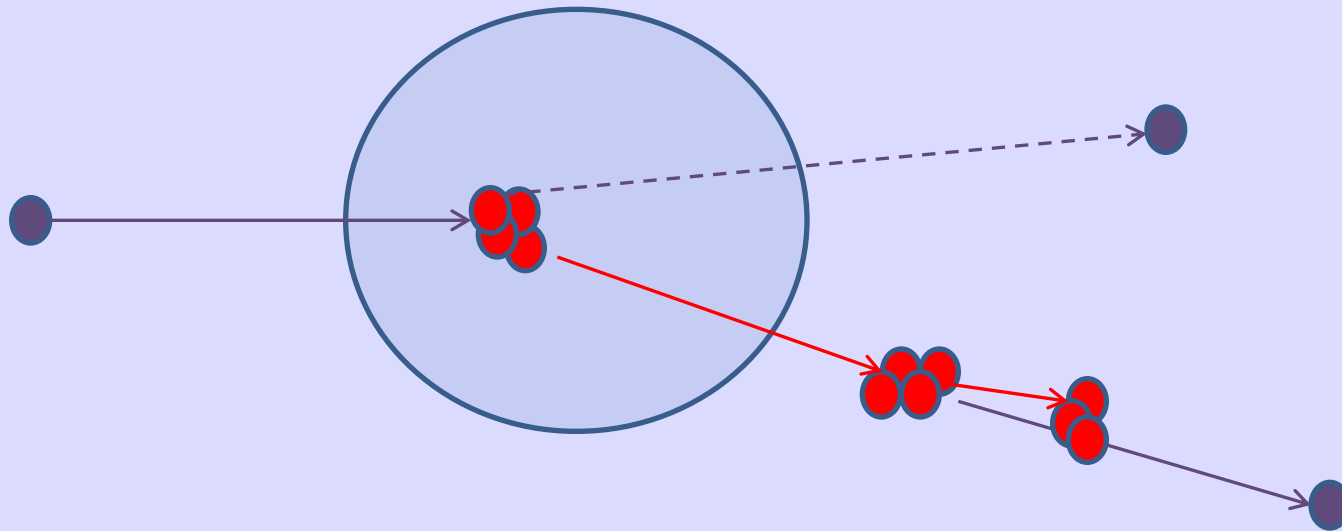


protons

$10^{12} - 10^{13}$ /цикл

Flucton fragmentation - same side flow

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

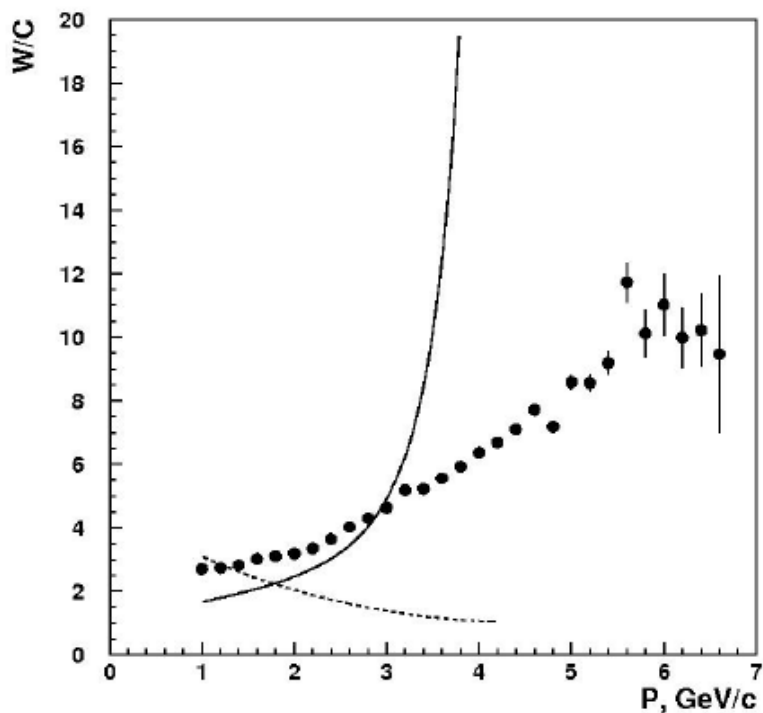


h^+ - spectrum

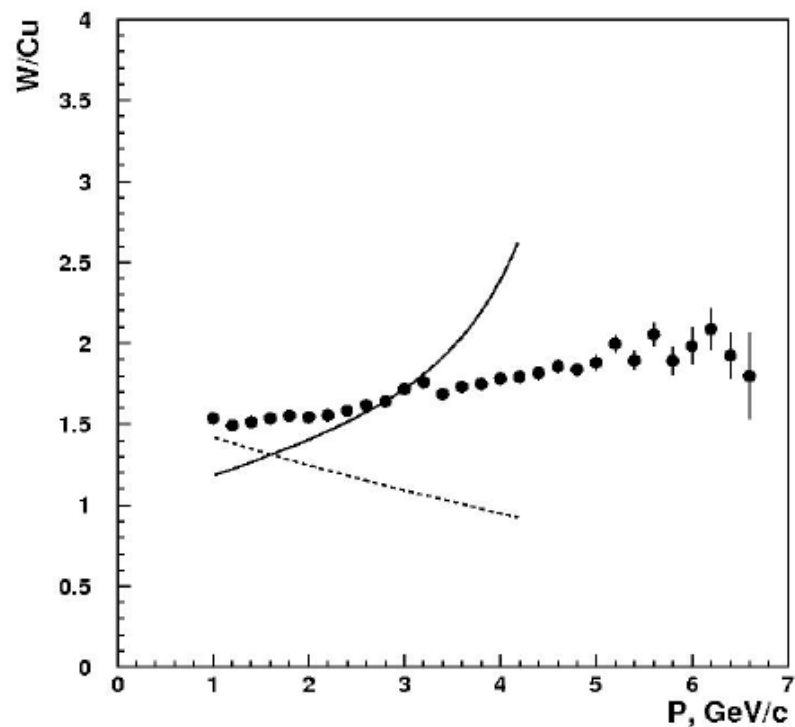
Сплошные кривые: HIJING 1.3 <http://www-nsdth.lbl.gov/~xnwang/hijing/doc.html>

Пунктирные кривые: UrQMD 3.3 <http://urqmd.org/>

W / C



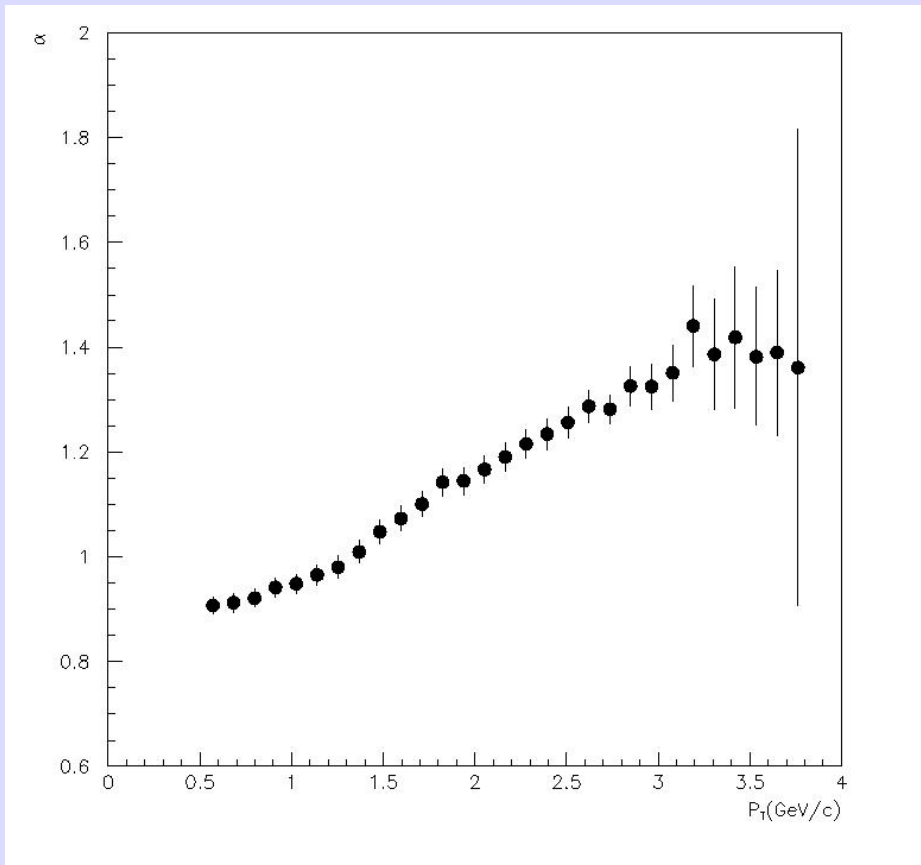
W / Cu



A-dependence

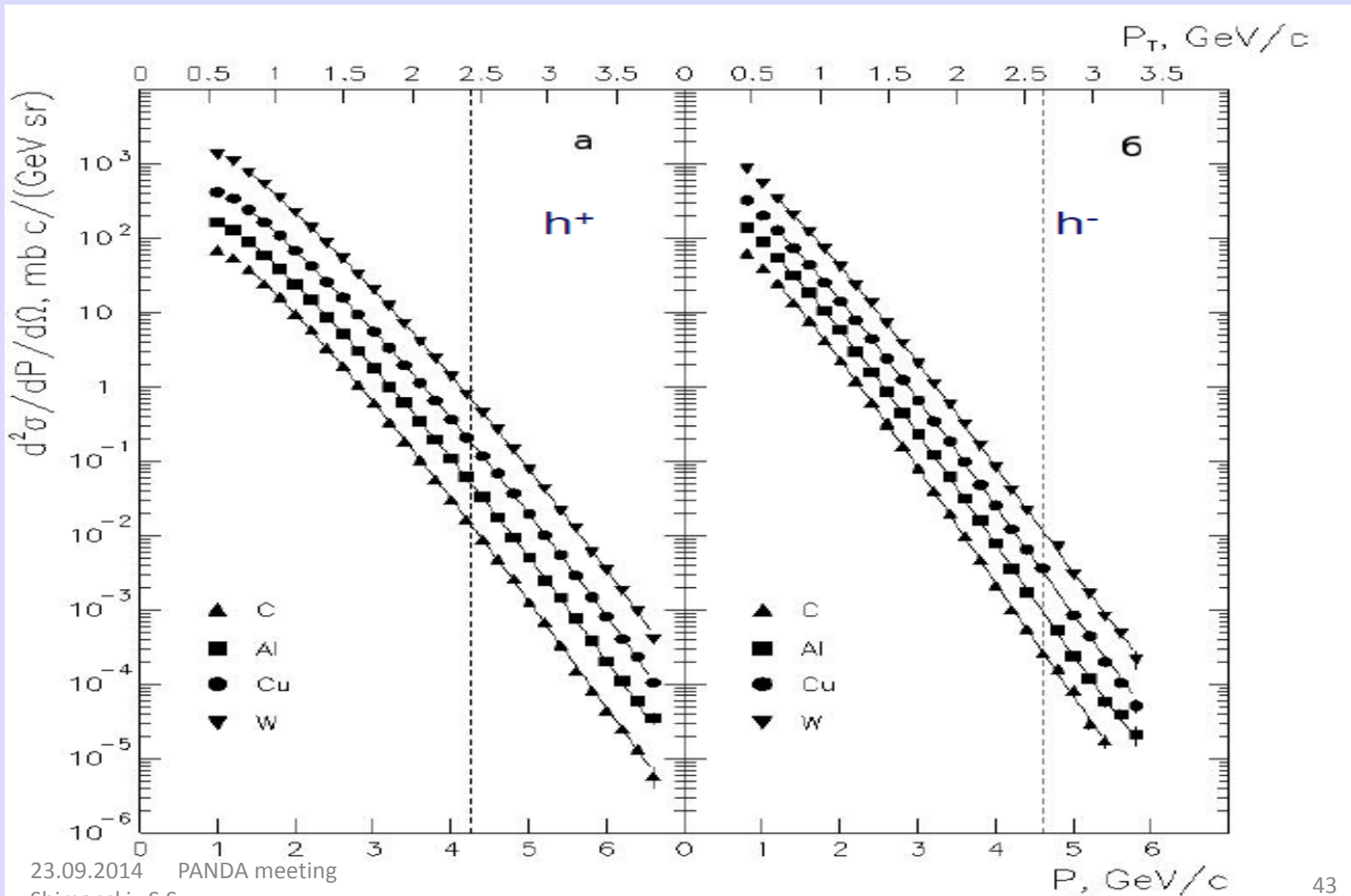
$$\sigma : A^\alpha$$

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

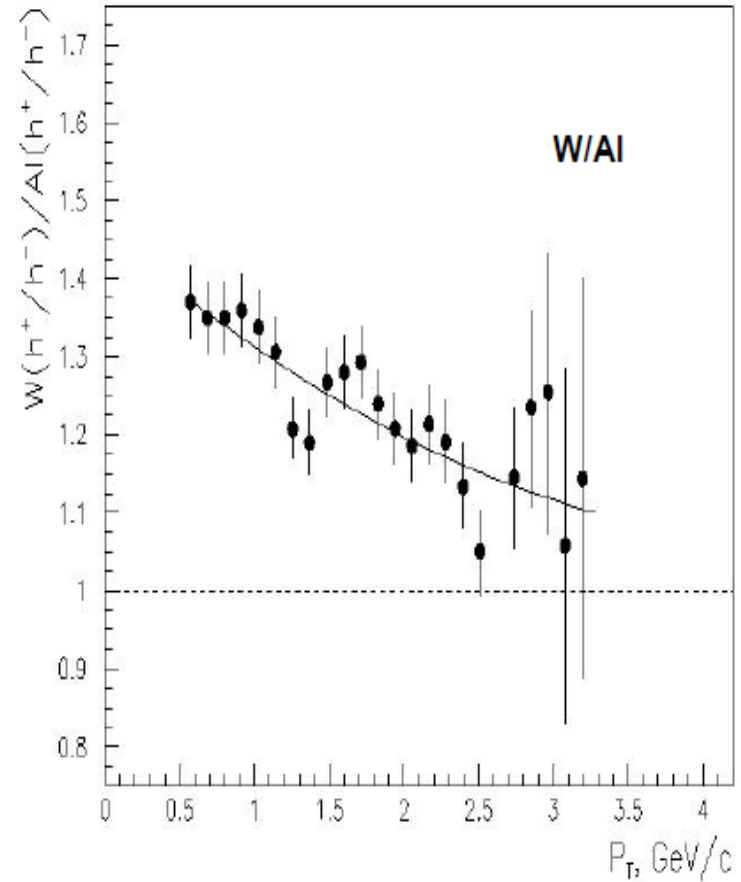
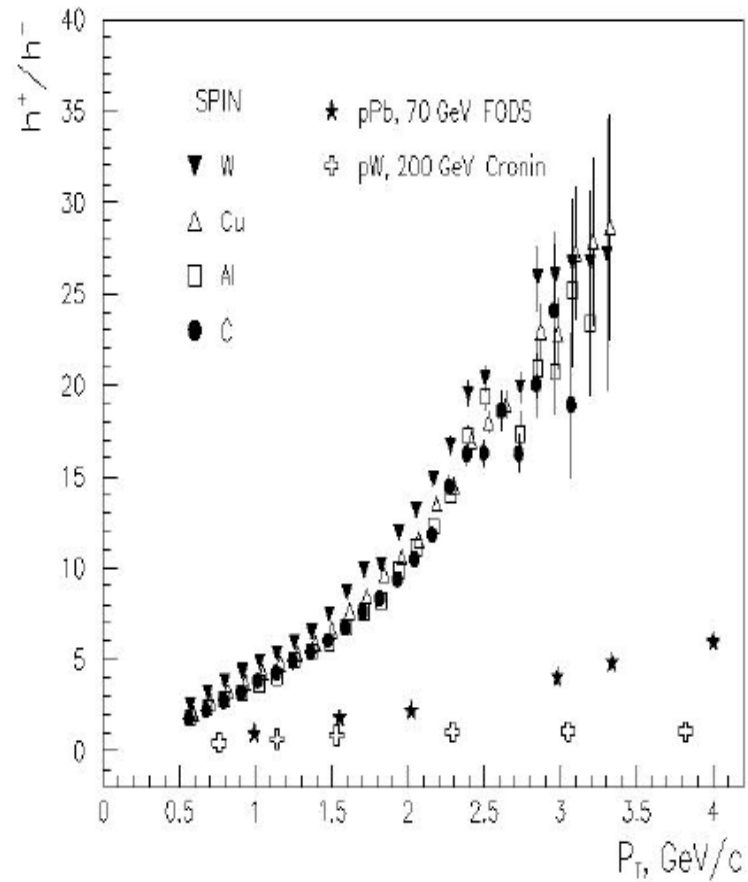


We deal with multinucleon configuration, but local this interaction?

[2012]



Ratio



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/с В ПРОТОН-ЯДЕРНЫХ СТОЛКНОВЕНИЯХ ПРИ 70 ГэВ

БАРКОВ Л. М., ЗОЛОТОРЕВ 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

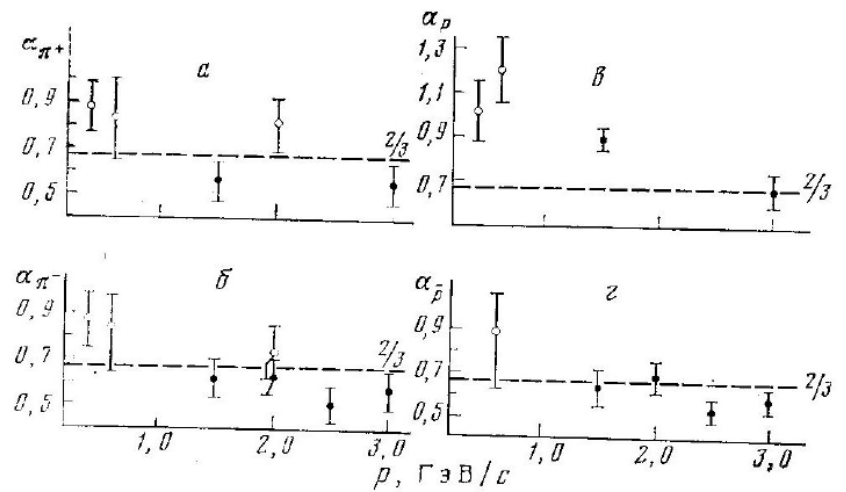


Рис. 4. Зависимость показателя α от импульса для положительных пионов (а), отрицательных пионов (б), протонов (в) и антипротонов (г) (● - [14], ○ - данная работа)

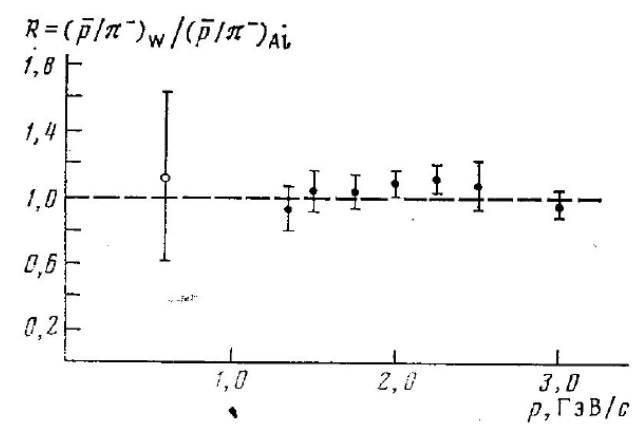
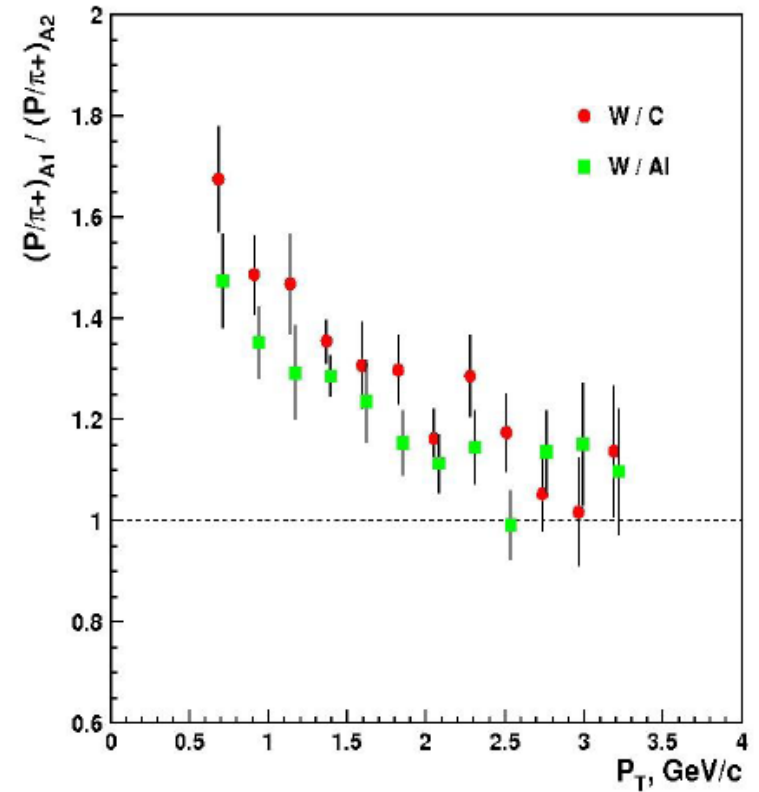
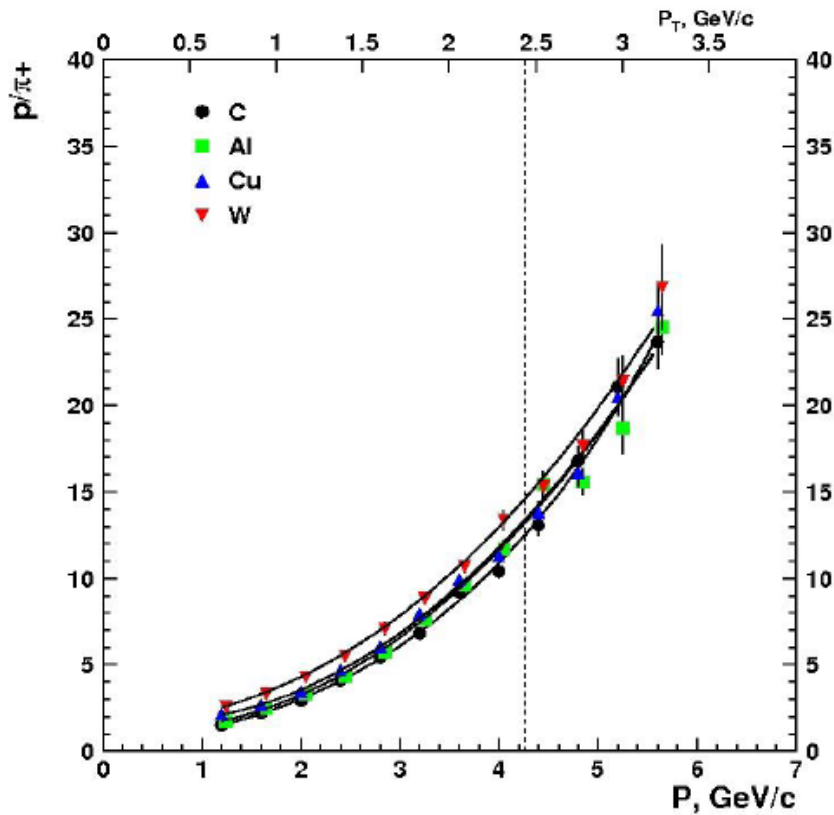


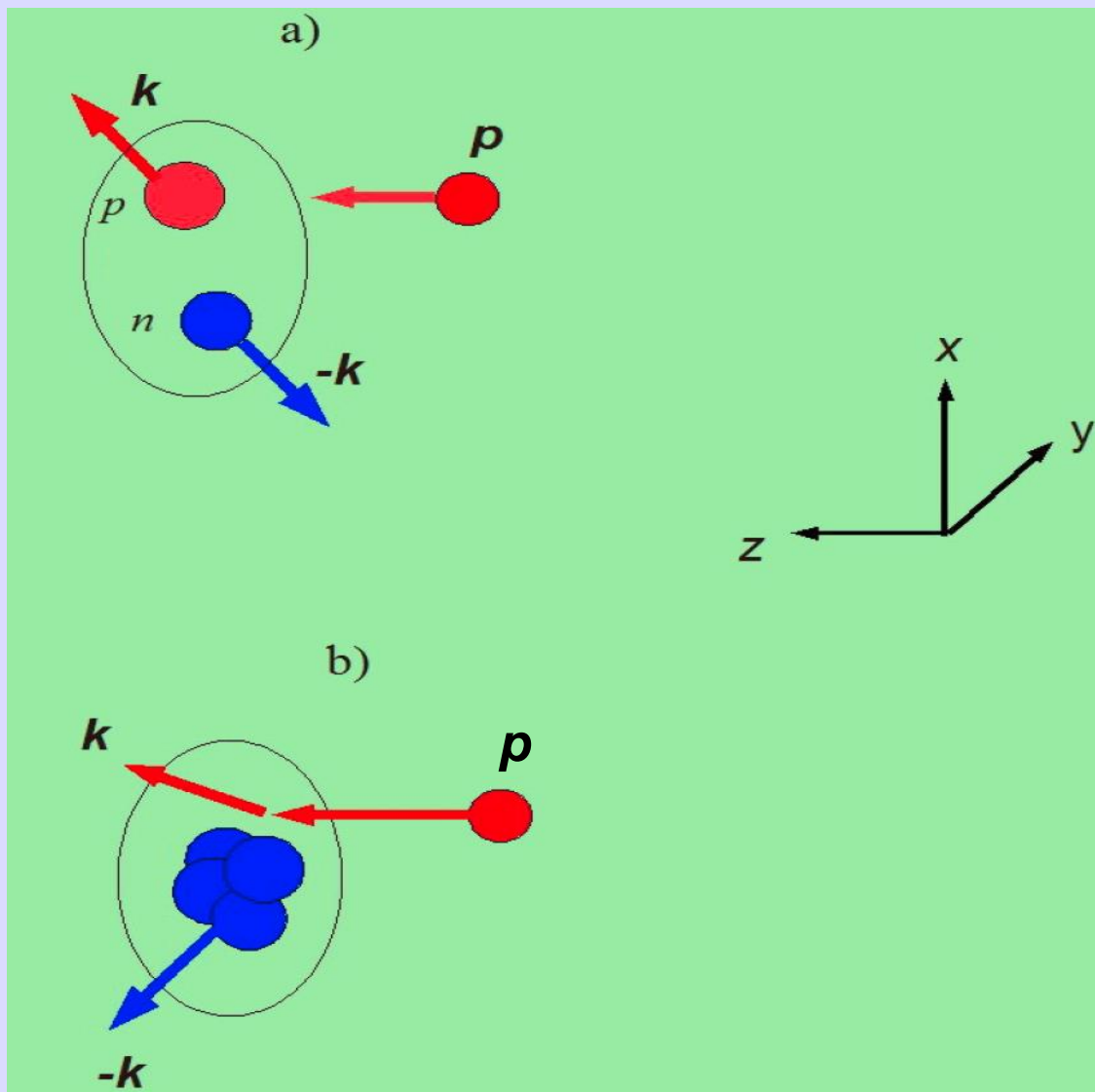
Рис. 6. Сравнение отношений выходов антипротонов и отрицательных пионов для W и Al мишеней в зависимости от импульса частиц (● - [11], ○ - данная работа)

Ratio p/π^+ (2013)



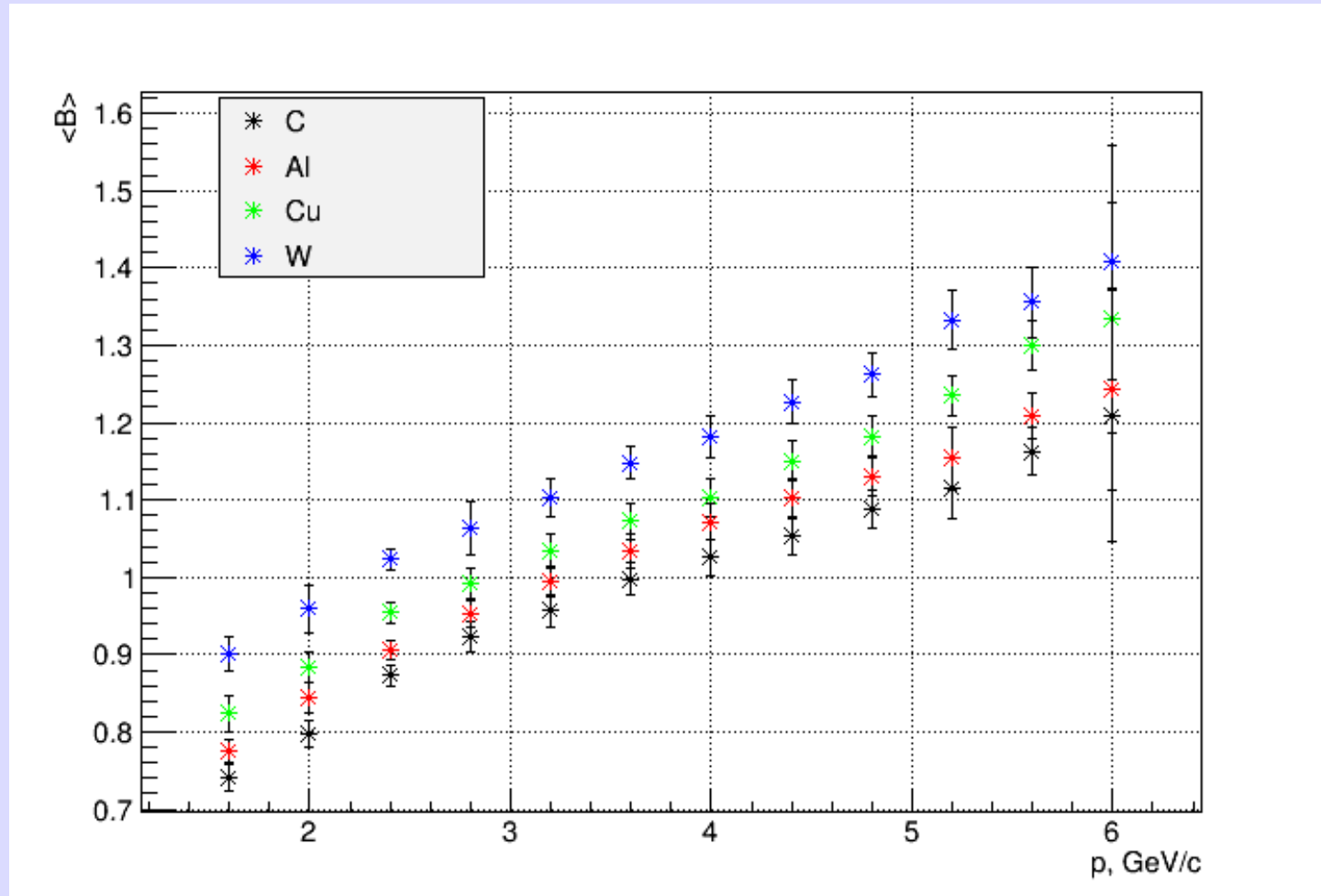
Knot out cold dense nuclear configurations

SRC configuration

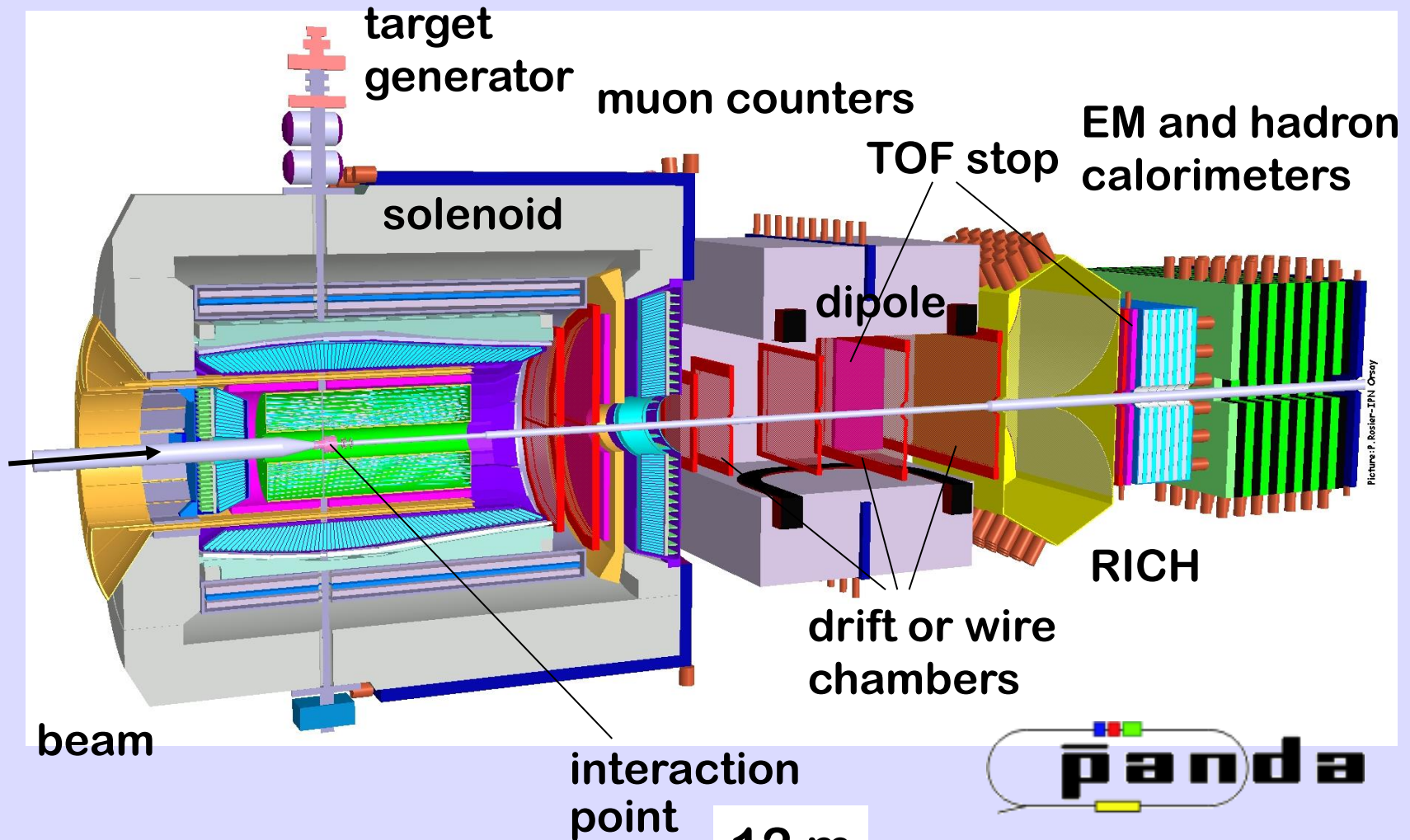


Multiquark configuration

Average baryon number $\langle B \rangle$



The PANDA Detector $\bar{p} + p(A) \rightarrow \bar{p}' + \{X\}$



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 pA - 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 $\bar{p} + A \rightarrow \bar{p} + \langle mN \rangle$, where m is an average number of nucleons.

The final state antiproton must have $x_T = \frac{2p_T}{\sqrt{s}} \sim 1$, where $s = (p_p + p_N)^2$. The aim is to see

the dependence on the cumulative number X . SRC mechanism predicts $\langle m \rangle \approx 1$ and no dependence on X .

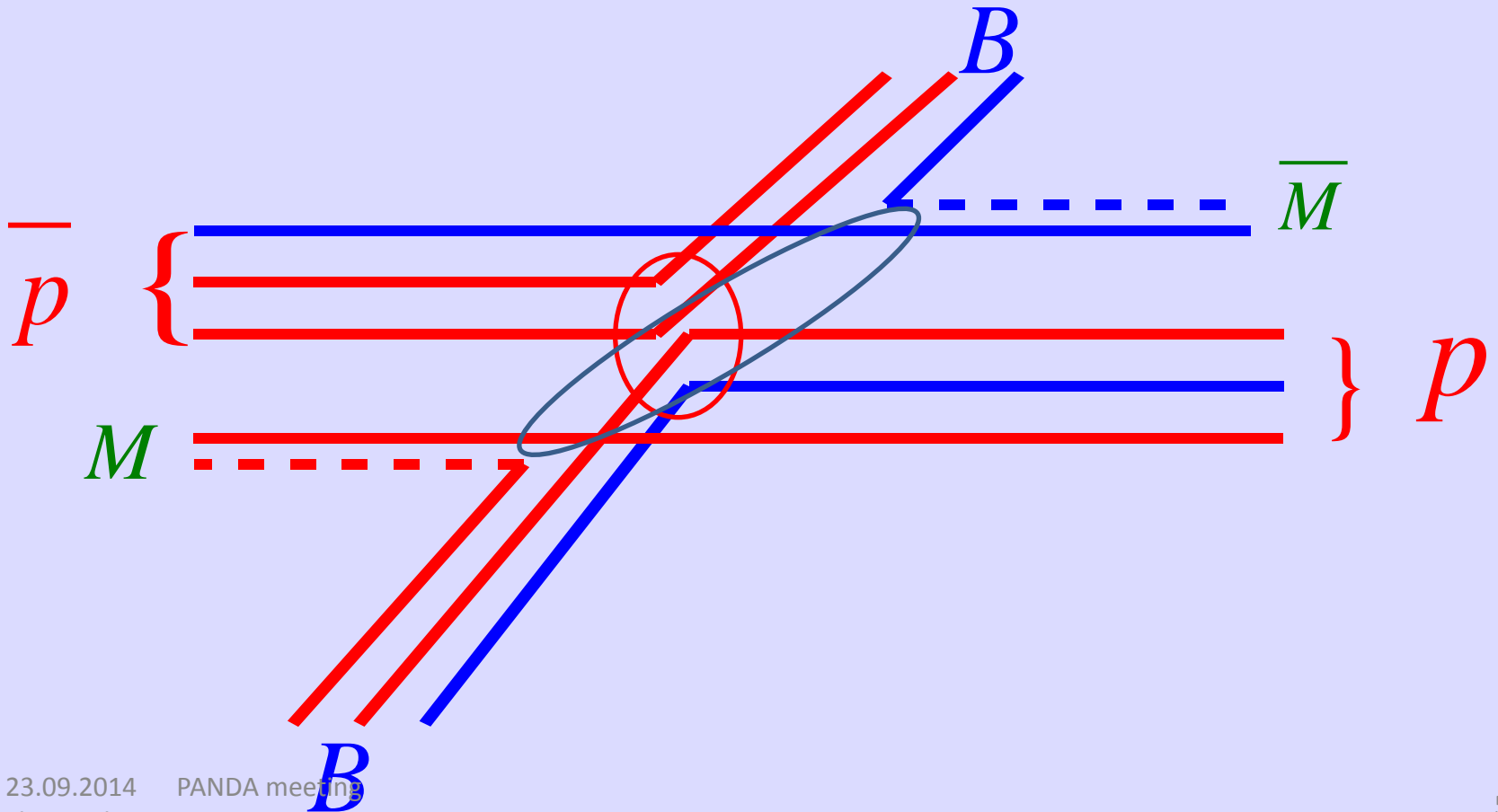
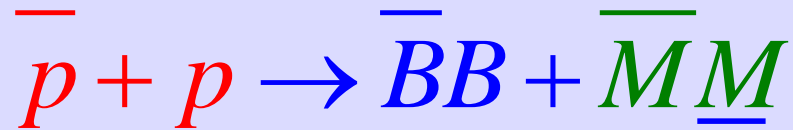
- The second process is the subthreshold J/Ψ (and D-mesons) production:

$\bar{p} + A \rightarrow J/\Psi + X \rightarrow \mu^+ \mu^- + X$ at $E_{beam} \geq 2 - 3$ GeV. Dimuon pair must have

$E^{inv} \geq 1.5$ GeV. The aim is to measure the cross section of this process which can be greater than the subthreshold cross section of antiproton production $p + A \rightarrow \bar{p} + X$ [8] which is already measured [4]. There is a prediction that the case $\sigma(\bar{p} + A \rightarrow J/\Psi + X) > \sigma(p + A \rightarrow \bar{p} + X)$ can be treated in favor of "flucton" hypothesis.

Exclusive reactions as way to resolve problems

$B(p, \Delta, \Delta\dots), M(\pi, K, l\dots)$



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

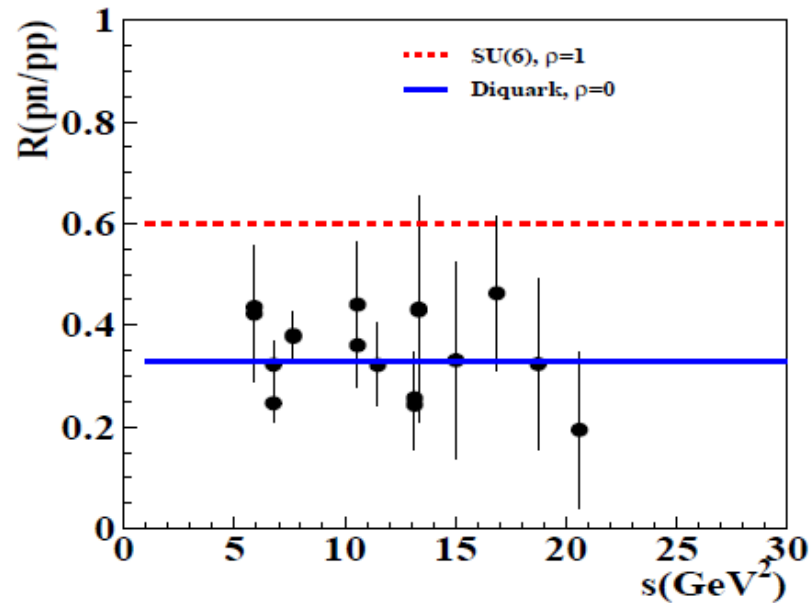


FIG. 2: (Color online) Ratio of the $pn \rightarrow pn$ to $pp \rightarrow pp$ elastic differential cross sections as a function of s at $\theta_{c.m.}^N = 90^\circ$.

Уважаемые коллеги,

...

С недавнего времени многопартонные взаимодействия (MPI) привлекают пристальное внимание как теоретиков, так и экспериментаторов. . . . На сегодняшний день теоретики разработали адекватный инструмент для описания двойных жёстких соударений – обобщённое двухпартонное распределение (generalized double parton distribution) \mathcal{G} . Адекватные монтекарловские модели для описания MPI находятся в стадии разработки. Используя данные HERA по электророждению векторных мезонов, структуру этого нового объекта можно предсказать в области $0.001 < x < 0.1$. В то же время, в области $x > 0.1$ информация о \mathcal{G} практически отсутствует. Пертурбативные эффекты в \mathcal{G} (весьма серьёзные при больших поперечных импульсах регистрируемых частиц и/или струй) находятся под контролем. Однако, о непертурбативной корреляции партонов внутри волновой функции адрона информации у нас нет. Без прямой экспериментальной информации прогресс в этой области вряд ли возможен. Важно, что для экспериментального изучения этих корреляций не нужны сверхвысокие энергии. Достаточно правильно заданных вопросов и грамотного поставленного эксперимента. Чрезвычайно важной представляется возможность разделения процессов по флейвору участвующих партонов. Измерять корреляции частиц в конечном состоянии вместо адронных струй представляется мне предпочтительным. Дело в том, что эта наблюдаемая содержит ту же информацию о корреляции начальных партонов, что и измерение струй, однако свободна от неопределённостей, связанных с выбором и использованием алгоритма по определению струй. ...

Ю. Докшицер

27.02.2013

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

$$\bar{p}p \rightarrow \bar{p}p$$

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

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

$$\bar{p}p \rightarrow \bar{p}p + \pi\pi (KK)$$

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

$$\bar{p}p \rightarrow \bar{\Delta}\Delta$$

Detail vertexes studies:

$$q(\bar{q}) + \bar{q}(q) - (\text{quark} - \text{antiquark})$$

$$q(\bar{q}) + \bar{q}\bar{q}(qq) - (\text{quark} - \text{antidiquark})$$

$$qq + \bar{q}\bar{q} - (\text{diquark} - \text{antidiquark})$$

Where is the most interesting
range for study?

$p_T \sim 2 \text{ GeV}/c$ anomaly

Тема

Re: Cumulative at high p_T

От

[Boris Kopeliovich](#)

Кому

[Stepan](#)

ОТВЕТИТЬ

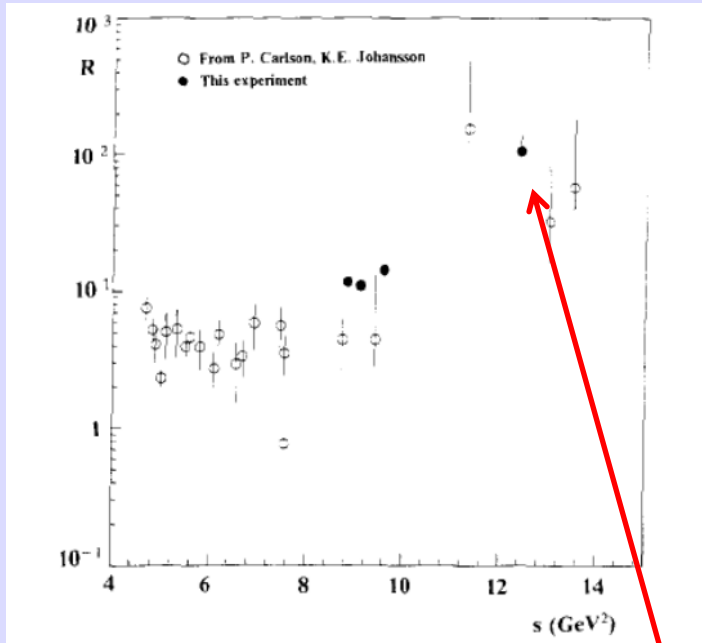
bzk@mpi-hd.mpg.de

Дата

23.01.2012 7:42

«I think that the main problem in understanding of high p_T hadrons at the energies of Serpukhov is why you see more protons than pions. This was claimed long time ago by the Sulyaev's group and I remember hot debates in that back in the 80s. Those debated ended up with no clear conclusion. Much later an excess of baryons was observed by the STAR at RHIC and was called "baryon anomaly". Again, no good explanation has been proposed so far. I might have my own explanation, but haven't written anything so far. Anyway, my point is, if we do not understand the mechanism of production of baryons dominating at high p_T , we should not make any certain conclusions about the cumulative mechanisms.»

$p\bar{p}$



$$R = \frac{\sigma(pp \rightarrow p\bar{p})}{\sigma(pp \rightarrow pp)} (90^\circ \text{ c.m.})$$

$p_T \sim 2 \text{ GeV}/c$ region

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

Cross-sections at 90 degrees

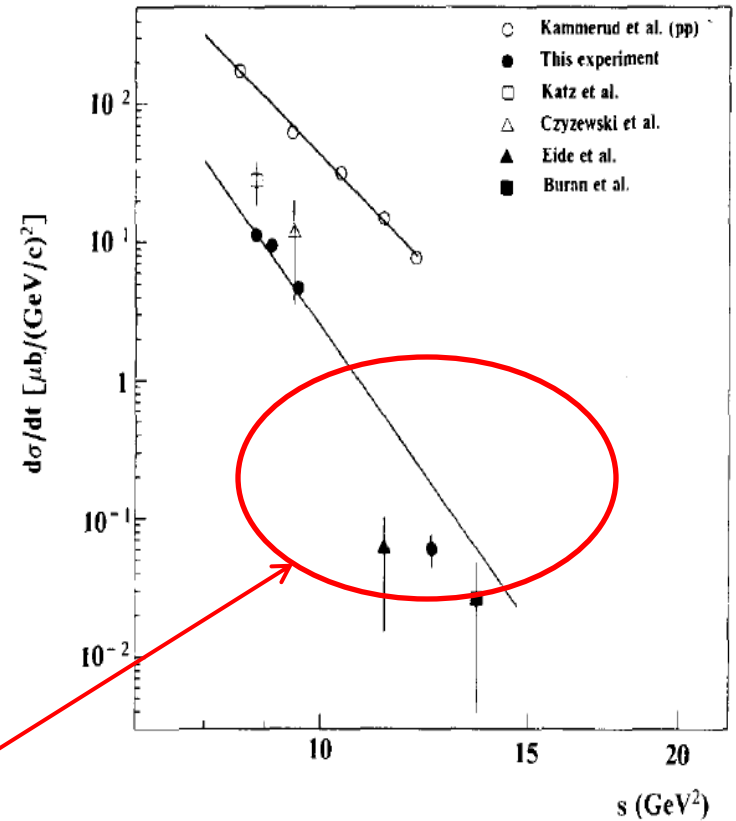
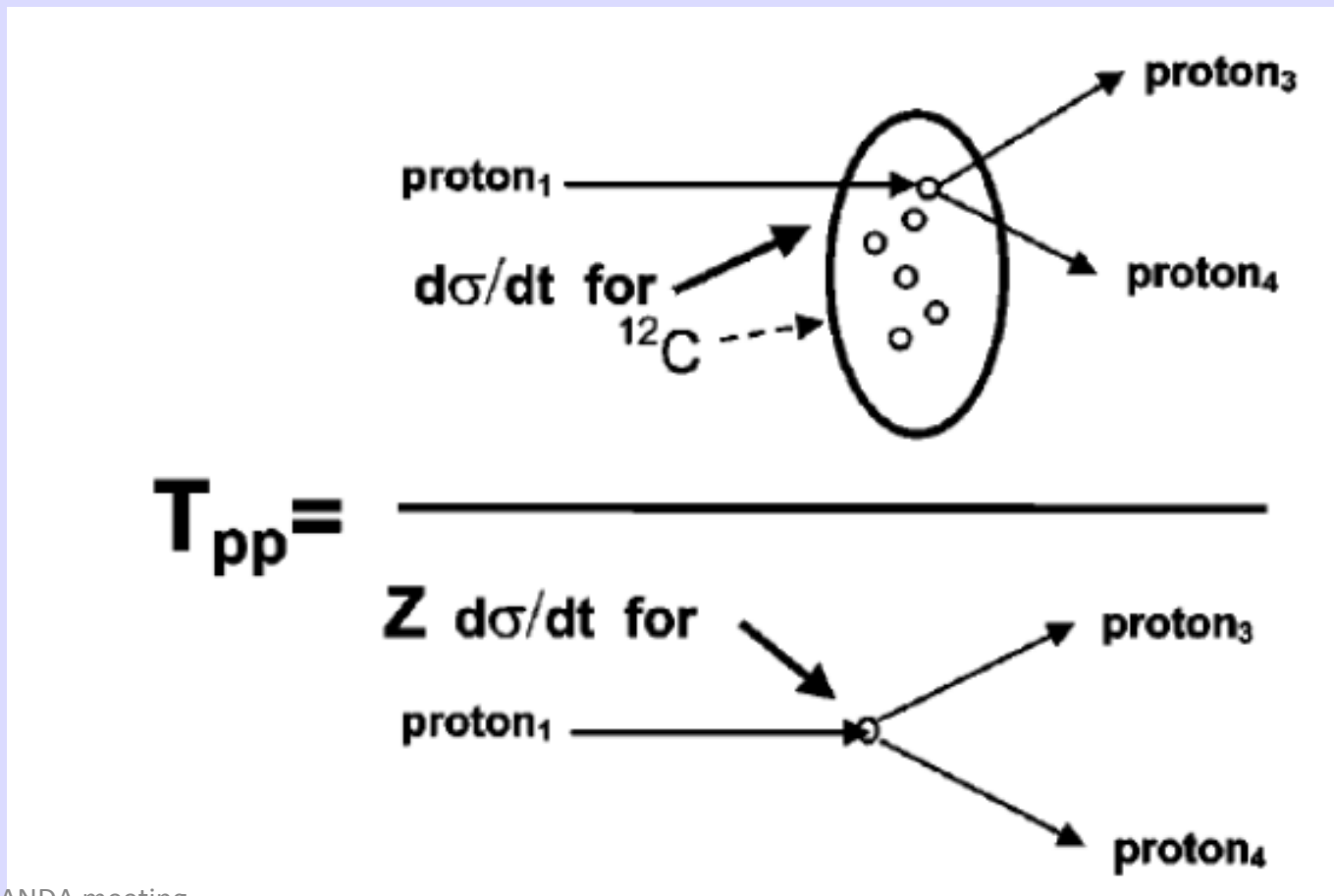


Fig. 3. The $p\bar{p}$ and pp elastic differential cross sections at 90° CM as function of the square of the CM energy, s . Open circles are pp data from ref. [6]. These data fit well to the drawn curve proportional to s^{-9} . The remaining points are $p\bar{p}$ data. Shaded from this experiment. Otherwise from ref. [7] (open square), ref. [8] (open triangle) ref. [9] (shaded triangle) and ref. [10] (shaded square). The lower curve is an s^{-n} fit to four data points of this experiment, neglecting systematic errors. One obtains $n=12.3 \pm 0.2$, but evidently the data do not seem to follow this kind of a power law.

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

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



Color(nuclear) transparency

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

A. Leksanov,⁵ J. Alster,¹ G. Asryan,^{3,2} Y. Averichev,⁸ D. Barton,³ V. Baturin,^{5,4} N. Bukhtoyarova,^{3,4} A. Carroll,³ S. Heppelmann,⁵ T. Kawabata,⁶ Y. Makdisi,³ A. Malki,¹ E. Minina,⁵ I. Navon,¹ H. Nicholson,⁷ A. Ogawa,⁵ Yu. Panebratsev,⁸ E. Piassetzky,¹ A. Schetkovsky,^{5,4} S. Shimanskiy,⁸ A. Tang,⁹ J. W. Watson,⁹ H. Yoshida,⁶ and D. Zhalov⁵

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

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

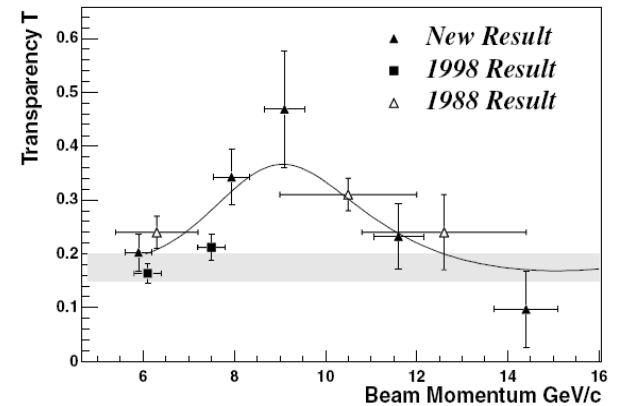
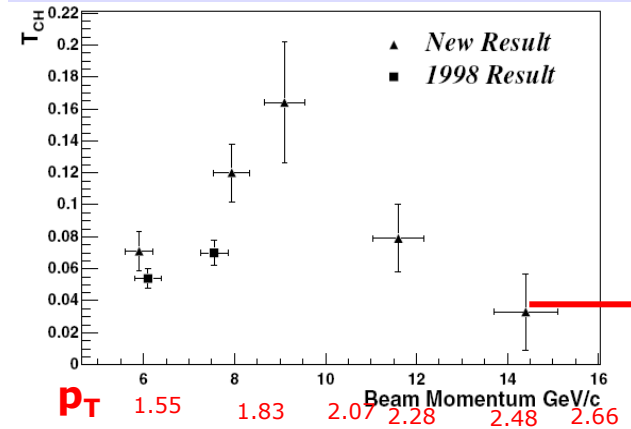


FIG. 2. Top: The transparency ratio T_{CH} as a function of the beam momentum for both the present result and two points from the 1998 publication [3]. Bottom: The transparency T versus beam momentum. The vertical errors shown here are all statistical errors, which dominate for these measurements. The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

The nuclear modification factor at RHIC and LHC

- quantify departure from binary scaling in AA
→ ratio of yield in AA versus reference collisions
- e.g.: reference is pp → R_{AA}

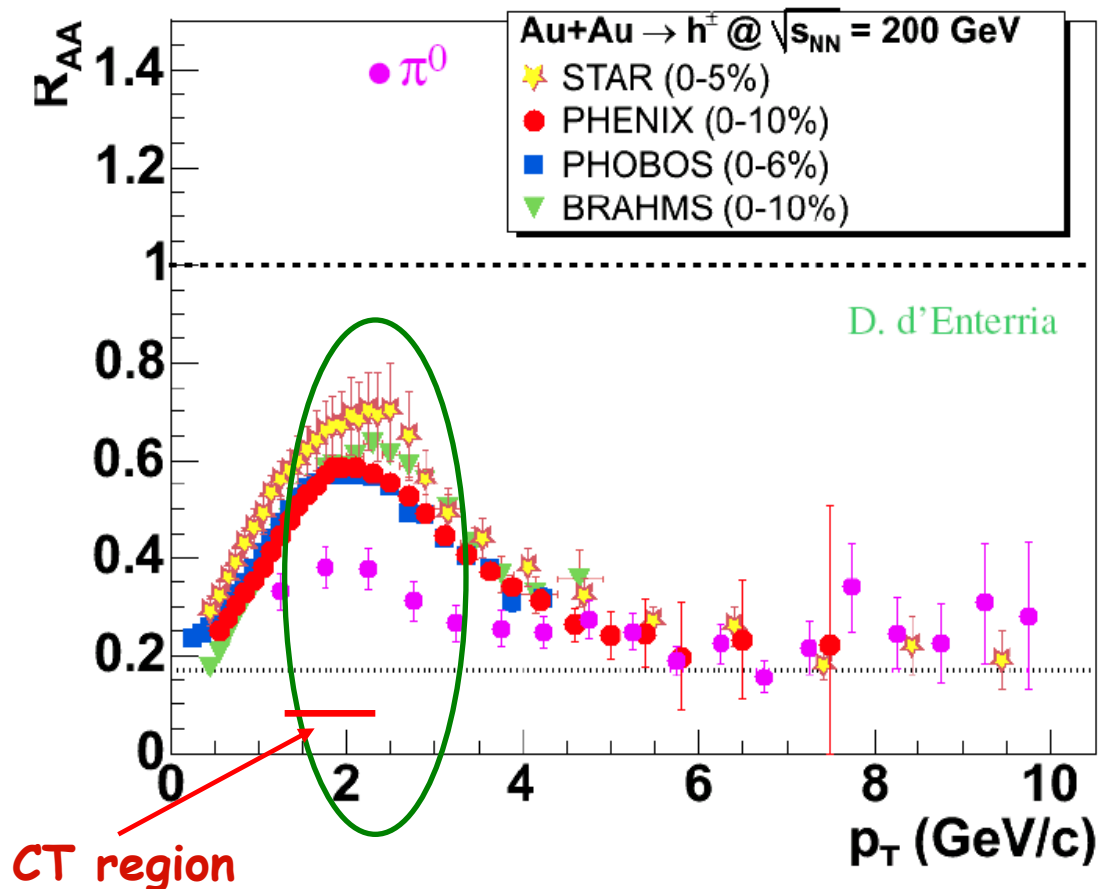
$$R_{AA} = \frac{\text{Yield}_{AA}}{\text{Yield}_{pp}} \cdot \frac{1}{\langle Nbin \rangle_{AA}}$$

- ...or peripheral AA → R_{cp} (“central to peripheral”)

$$R_{cp} = \frac{\text{Yield}_{AA, \text{central}}}{\text{Yield}_{AA, \text{periph}}} \cdot \frac{\langle Nbin \rangle_{AA, \text{periph}}}{\langle Nbin \rangle_{AA, \text{central}}}$$

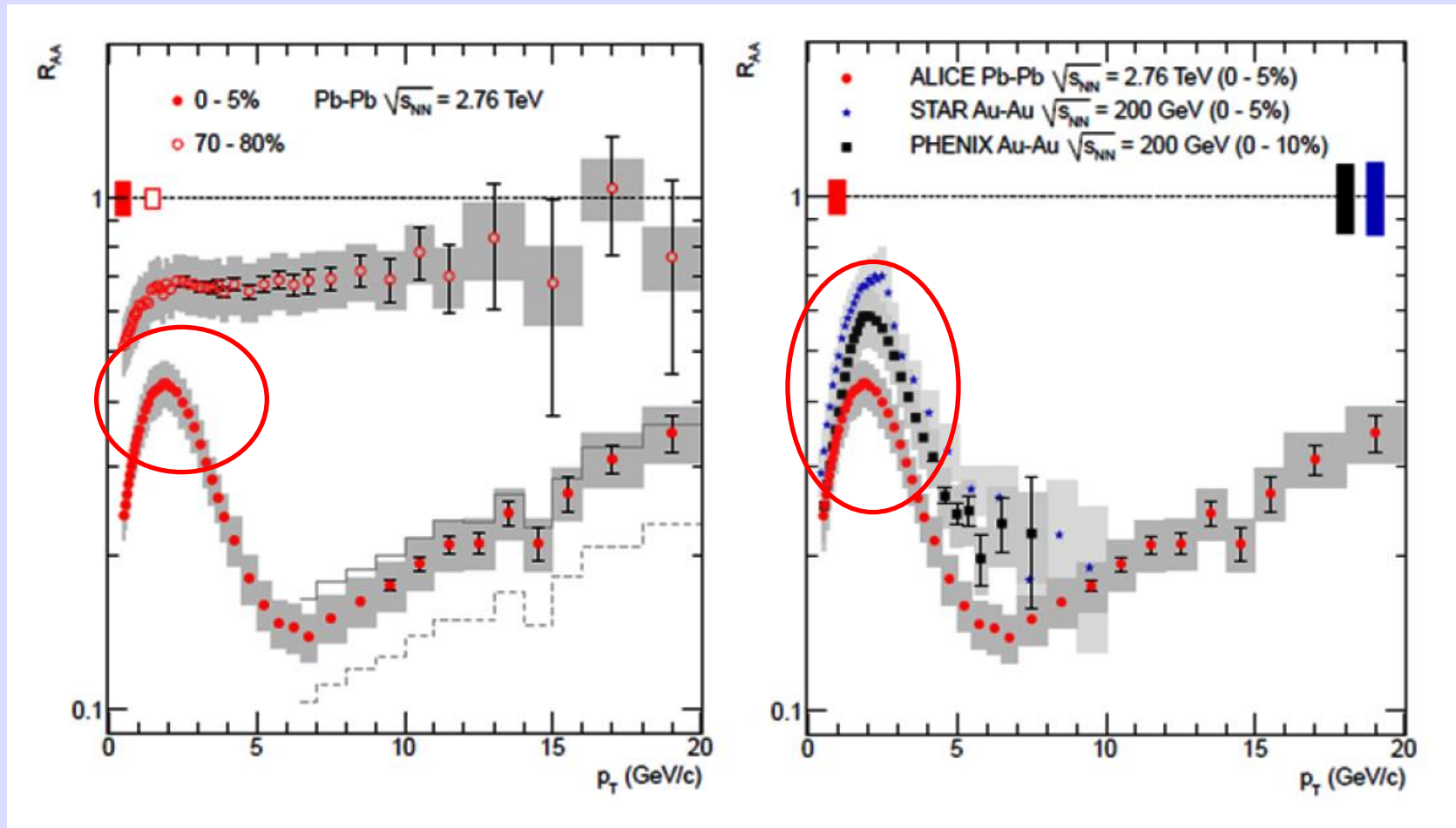
high p_t suppression seen by all experiments

$$R_{AA} = \text{yield}(\text{AuAu}) / N_{\text{coll}} \text{ yield}(\text{pp})$$

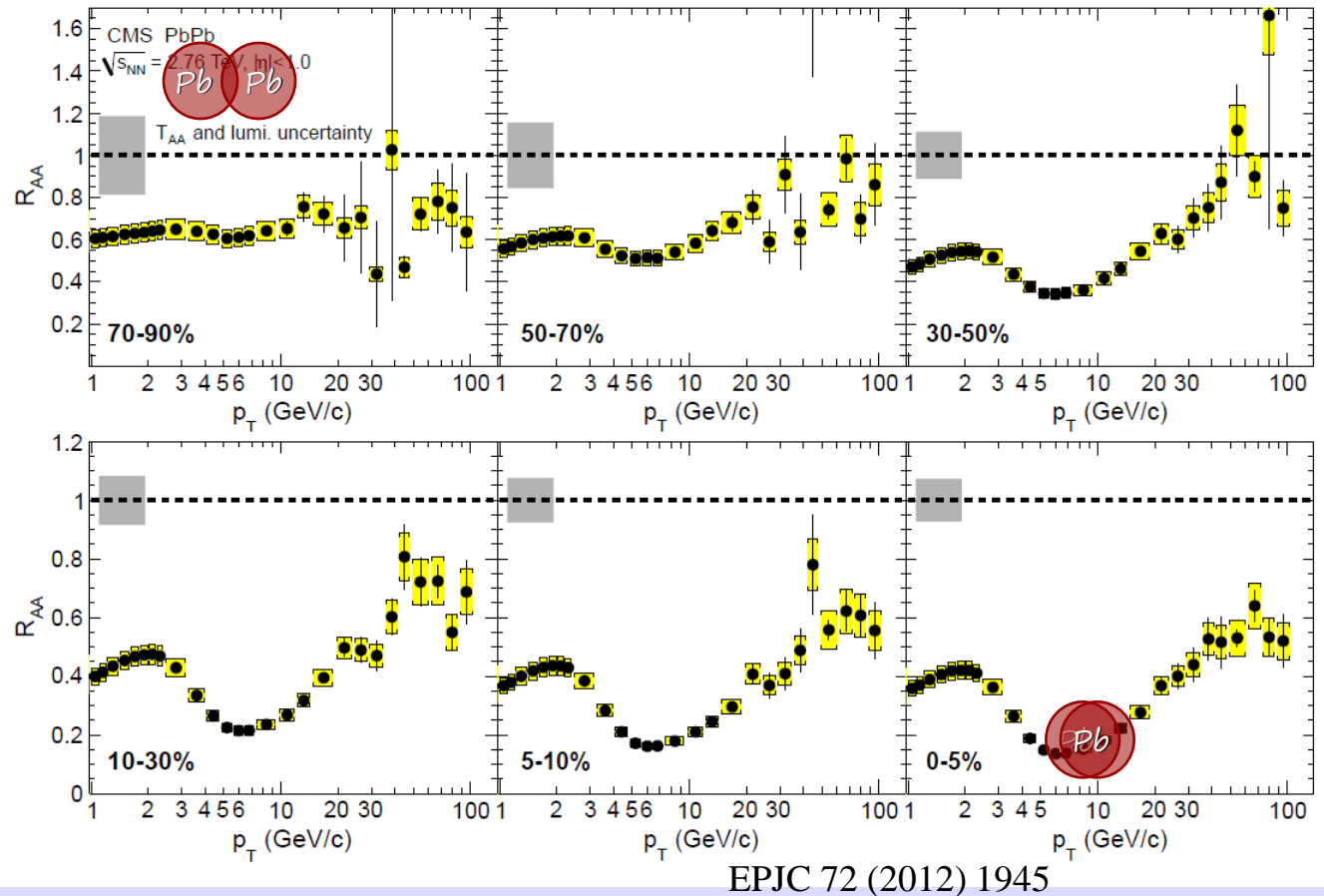


- ★ all expts. see large suppression in AuAu
- ★ π^0 lower than h^\pm
- ★ no suppression in dAu rather Cronin enhancement \rightarrow medium effect, not incoming partons
- \rightarrow reasonable agreement between 4 experiments

$p_T \sim 2$ GeV/c anomaly at high energy (RHIC and LHC)



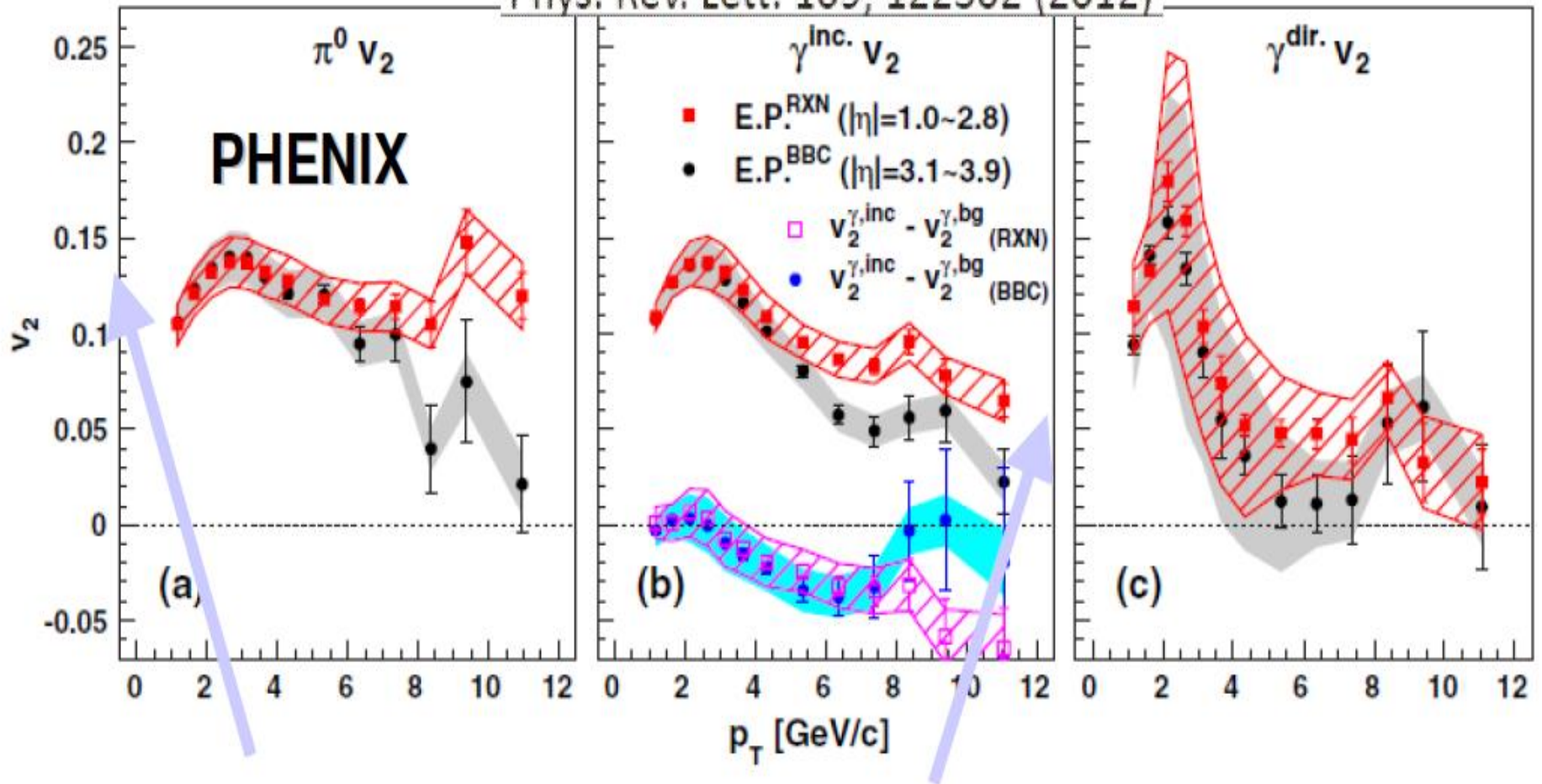
Charged hadron suppression in Pb-Pb



$$R_{AA} = \frac{N_{Jet}^{AA} / N_{coll}}{N_{Jet}^{pp}}$$

For central collisions:

- A pronounced minimum at $P_T = 6 - 7 \text{ GeV}$ where $R_{AA} \approx 0.2$
- At higher P_T R_{AA} rises and levels off above 40 GeV
- Suppression at high P_T at the same level as jet suppression



$p_T \sim 2 \text{ GeV}/c$ region

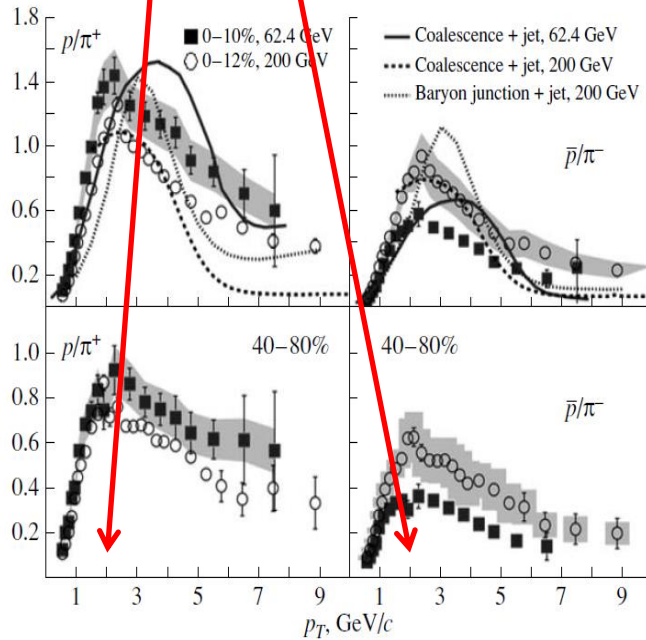


Fig. 3. [10] Ratio of the cross sections for the production of protons and charged pions as a function of the transverse momentum for various degrees of centrality and two beam energies of 62.4 and 200 GeV: (points) results of the STAR experiment and (curves) results of model calculations.

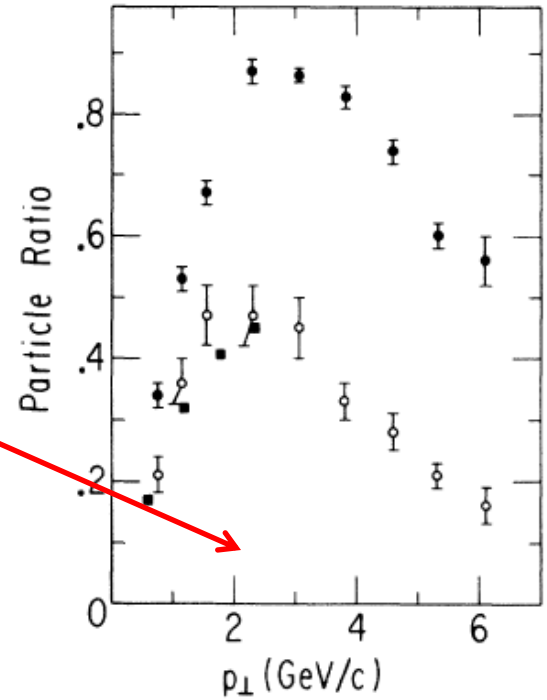
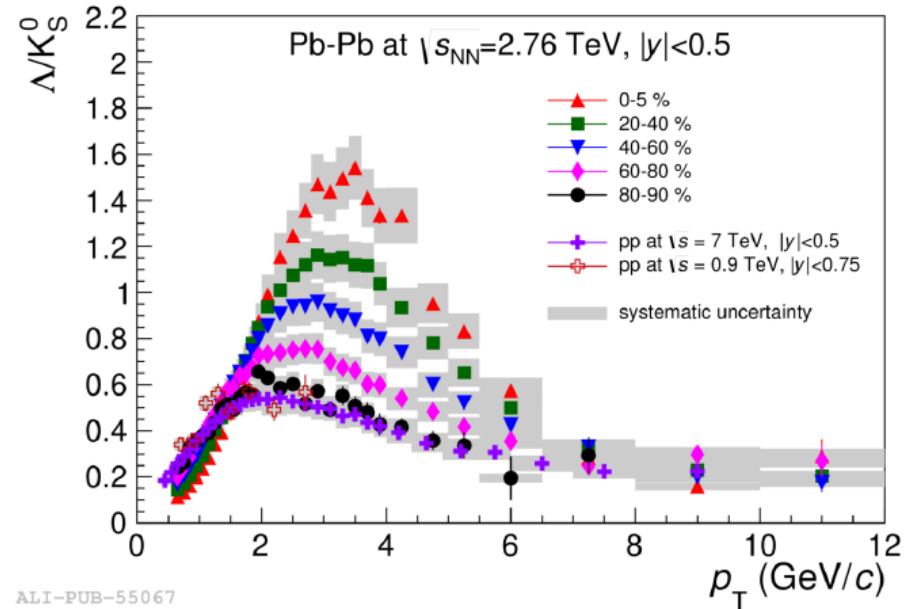
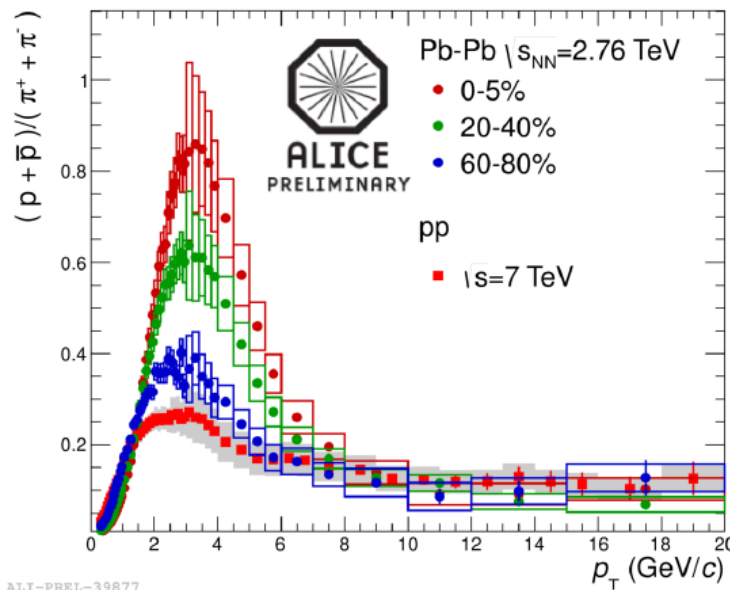


FIG. 20. Comparison of the cross-section ratio p/π^+ measured on tungsten at $\sqrt{s} = 23.7 \text{ GeV}$ (closed circles), with that obtained by extrapolation to $A = 1$ (open circles). Ratios obtained from the British-Scandinavian collaboration (Ref. 23) at $\sqrt{s} = 23.4 \text{ GeV}$ are also plotted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



Baryon anomaly in Pb-Pb

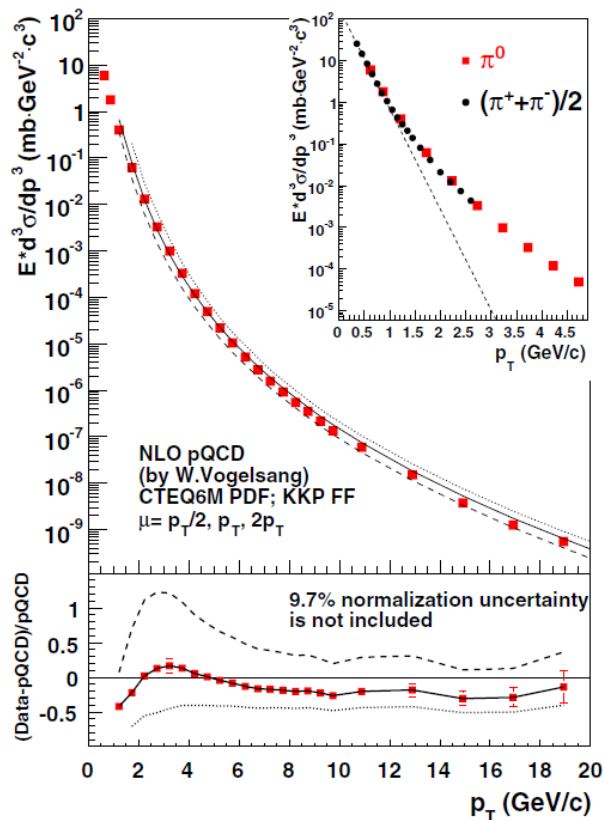


- Baryon to meson ratio increasing with centrality for $p_T < 8$ GeV/c.
 - Enhancement at moderate p_T is consistent with radial flow
 - May be explained by quark recombination from QGP (coalescence model)
- For $p_T > 8$ GeV/c no dependence on centrality and collision system
 - Consistent with fragmentation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

pp \rightarrow $\pi + X$

PHYSICAL REVIEW D 76, 051106(R) (2007)

Inclusive cross section and double helicity asymmetry for π^0 production in $p + p$ collisions at $\sqrt{s} = 200$ GeV: Implications for the polarized gluon distribution in the proton



for higher p_T . This is the basis for applying the pQCD formalism to the double helicity asymmetry data with $p_T > 2$ GeV/c.

PHYSICAL REVIEW D 79, 012003 (2009)

Inclusive cross section and double helicity asymmetry for π^0 production in $p + p$ collisions at $\sqrt{s} = 62.4$ GeV

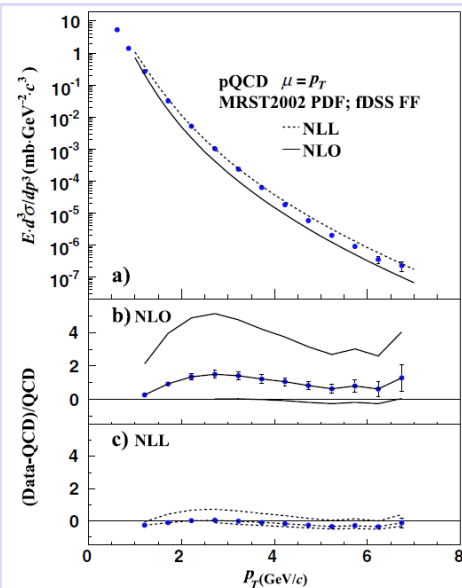


Fig. 4(b). A similar drop in the parameter n at $x_T \approx 0.1$ was observed at ISR energies [12]. Figure 4(b) also shows the possible transition from soft- to hard-scattering regions in π^0 production at $p_T \sim 2$ GeV/c. A similar conclusion was derived from the shape of the π^0 spectrum at $\sqrt{s} = 200$ GeV in [5]. This can serve as a basis for applying the pQCD formalism to the double helicity asymmetry data with $p_T > 2$ GeV/c in order to allow access to ΔG .

$p \uparrow p \uparrow \rightarrow pp(90^\circ)$

E.A. Crosbie et al., Phys.Rev. D, vol.23, N3,1981

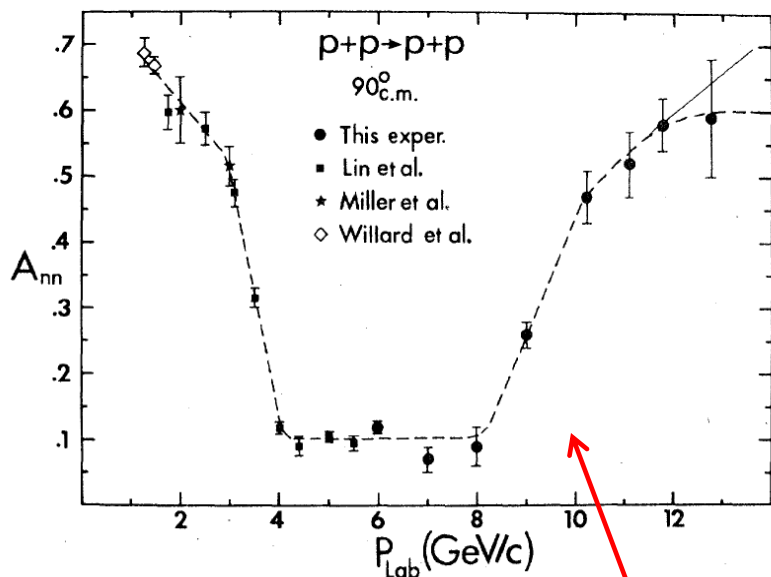


FIG. 2. Plot of the spin-spin correlation parameter A_{nn} for $p+p \rightarrow p+p$ at $90^\circ_{c.m.}$ as a function of incident beam momentum. The dashed and solid lines are hand-drawn possible fits.

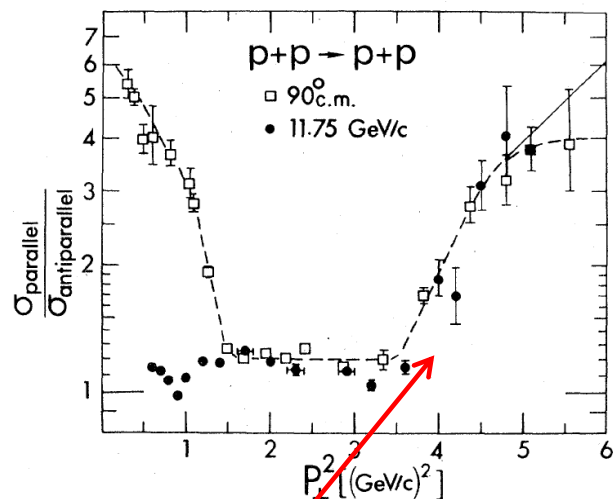


FIG. 3. Plot of the ratio of the spin-parallel to spin-antiparallel differential cross sections, as a function of P_\perp^2 , for $p-p$ elastic scattering. The squares are the fixed-angle data at $90^\circ_{c.m.}$, with the incident energy varied. The circles are data (Refs. 5, 11) with the momentum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

END

Review

Color transparency: Past, present and future

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ARTICLE INFO

Keywords:

QCD in Nuclei

Color transparency

Onset

Exclusive processes

ABSTRACT

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.

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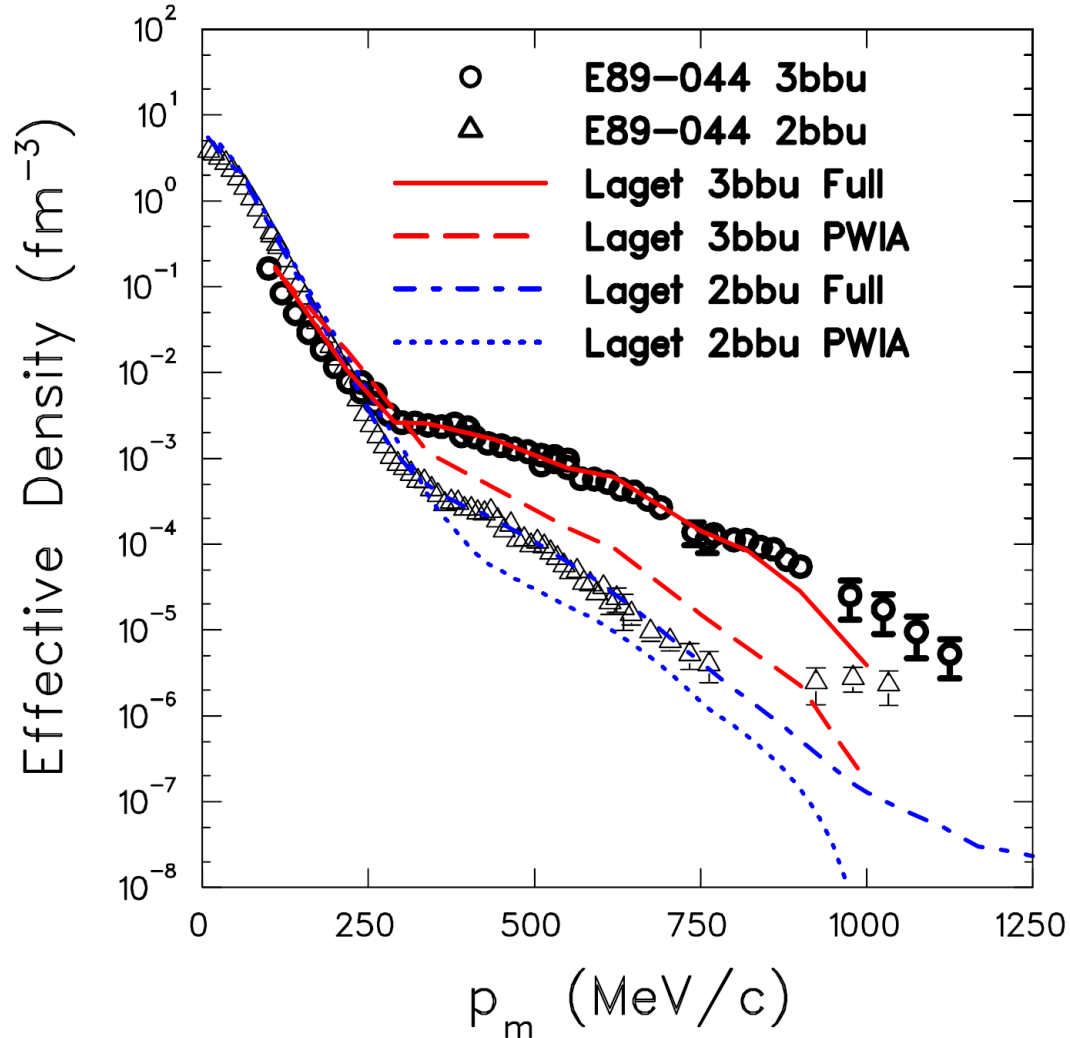
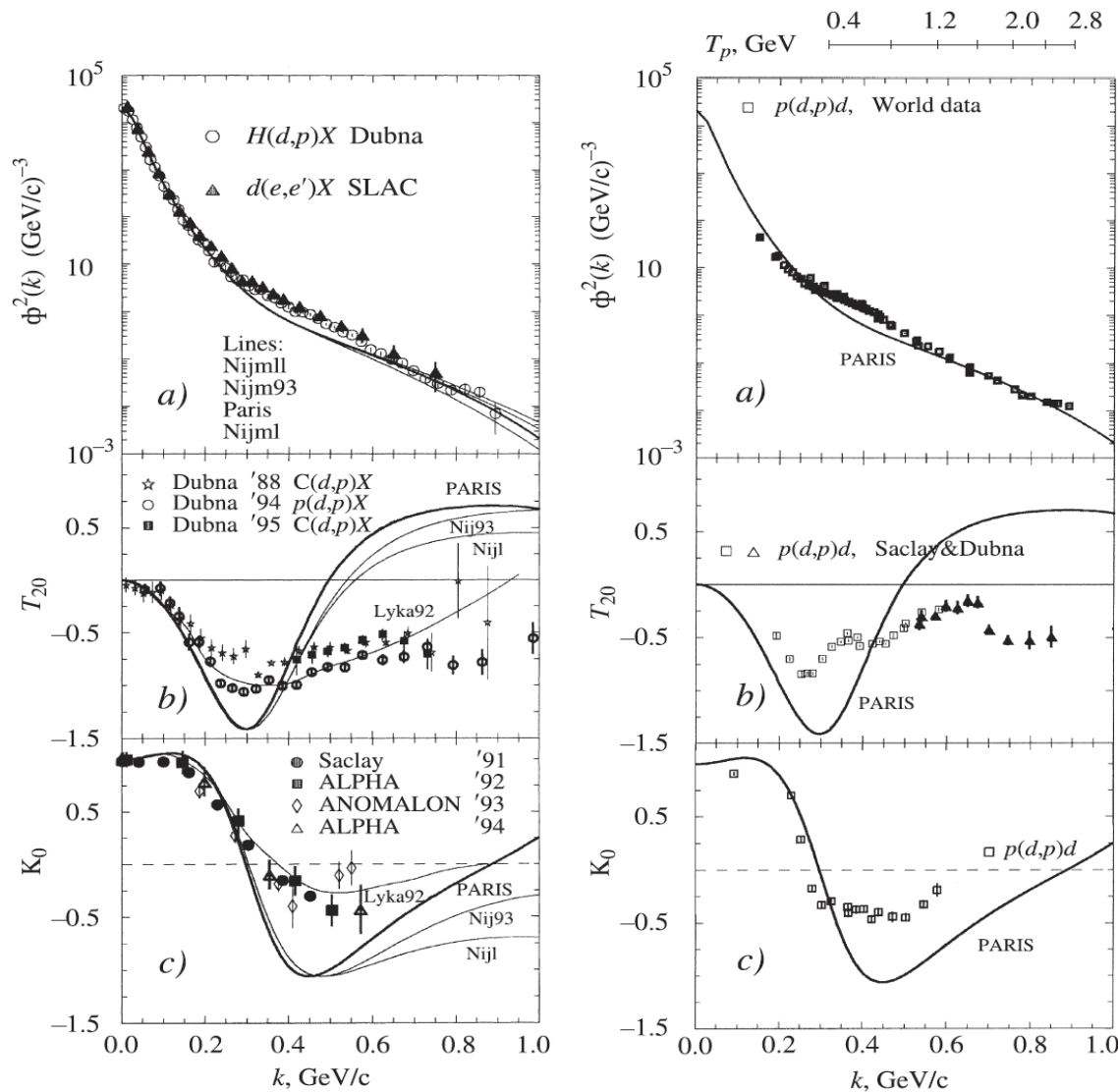


Figure 3. Proton effective momentum density distributions in ^3He extracted from $^3\text{He}(e, e'p)pn$ three-body break-up (3bbu) is shown as the open black circles and the $^3\text{He}(e, e'p)d$ two-body break-up (2bbu) is shown as open black triangles. The three-body break-up (3bbu) integration covers 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.

CURRENT EXPERIMENTS USING POLARIZED BEAMS OF THE JINR VBLHE ACCELERATOR COMPLEX

F. Lehar

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



23.09.2014 PANDA meeting
 Shimansky S.S.
 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



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

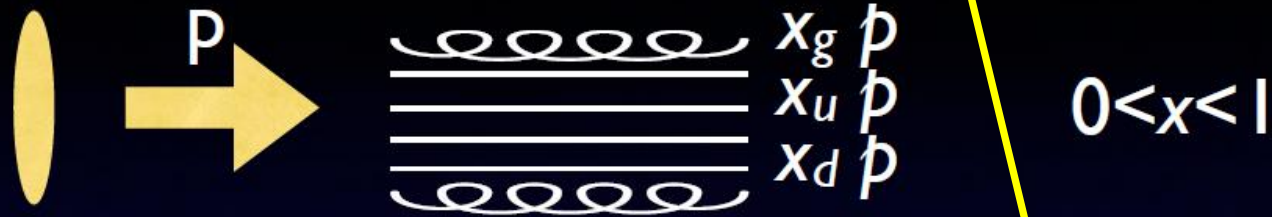
RHIC Scientists Serve Up “Perfect” Liquid

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.

PDF

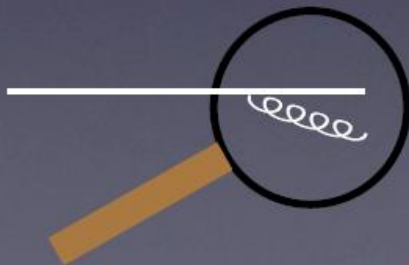


probability to find a “parton” i of momentum $x p$
 parton distribution function $f_i(x_i)$

$p p$ collision = sum of parton-parton collision

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

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



DGLAP equation

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