"Новая физика в эксперименте SPD на коллайдере НИКА"

С.С. Шиманский (ОИЯИ)

С 25-ти летием участия в эксперименте ALICE!!!

Letter of Intent for A Large Ion Collider Experiment

ALICE Collaboration (N. Antoniou (Athens U.) et al.). Mar 1993. 61 pp.
(N. Antoniou ,), R. Bock, R. Brockmann, H. Gutbrod, B. Kolb, A. Sandoval, H.R. Schmidt (Darmstadt, GSI), V. Arefev, G. Agakishiev, V. Astakhov, A. Baldin, B. Batyunya, Z. Borisovskaya, O. Gavrishchuk, B. Guskov, I. Kosarev, A. Maksimov, A. Malakhov, P. Nomokonov, Yu. Panebrattsev, A. Senner, I. Shelaev, Yu. Shishov, S. Shimansky, N. Slavin, A.S. Vodopianov, Yu. Zanevsky (Dubna, JINR), D. Ferenc, M. Gazdzicki, R. Renfordt, D. Rohrich, R. Stock, H. Strobele, S. Wenig (), V.G. Baryshevsky, A.A. Fedorov, M.V. Korzhik (Belarus State U.), D. D'Arrigo, G. Giardina, M. Herman, A. Taccone (Messina U.), A.A. Baldin, S.N. Filippov, Yu.K. Gavrilov, , H. Beker, S. Di Liberto, M.A. Mazzoni, F. Meddi, G. Rosa (Rome U. & INFN, Rome), Vladimir A. Andrianov, M.A. Braun, P. Danilov, G.A. Feofilov, A.A. Kolozhvarii, V. Semenov, T.A. Tulina, F.F. Valiev, V.V. Vechernin, L.I. Vinogradov, M.I. Yudkin (St. Petersburg State U.), E. Agterhuis, J. Blom, A. van den Brink, **CERN-LHCC-93-16, CERN-LHCC-I-4, 1993**

Pulse height measurements and electron attachment in drift chambers operated with Xe, CO(2) mixtures ALICE Collaboration
(A. Andronic et al.). Mar 2003. 19 pp.
Published in **Nucl.Instrum.Meth. A498 (2003) 143-154**
DOI: 10.1016/S0168-9002(02)02083-1
e-Print: physics/0303059

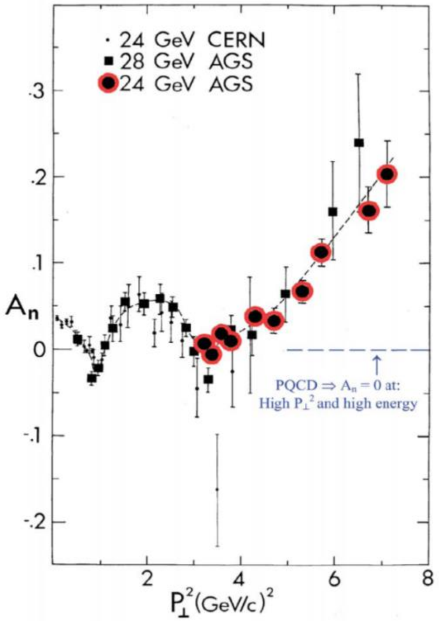
The ALICE Transition Radiation Detector: construction, operation, and performance
ALICE Collaboration (Shreyasi Acharya (Calcutta, VECC) et al.). Sep 8, 2017. 40 pp.
Published in **Nucl.Instrum.Meth. A881 (2018) 88-127**
CERN-EP-2017-222
DOI: 10.1016/j.nima.2017.09.028
e-Print: arXiv:1709.02743

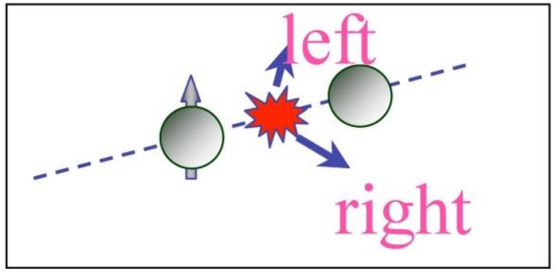
Towards full-scale SPD project

(status)

Asymmetries in high p_T hadron production

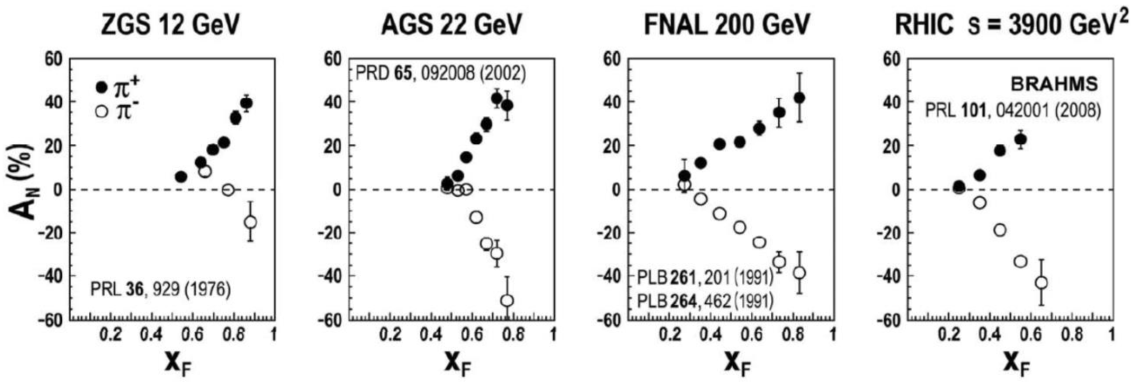
- Diquark properties.
- Confinement laws.
- Nature of the huge spin effects.
- Deuteron spin structure.
- Properties of the plain NΛ- and NK-interactions.
- Exotic states – H(ΛΛ), pentaquarks, …
- Nature and properties of the cold super dense baryonic matter (CsDBM) (pA and AA).
- Dilepton production puzzle in np-interaction.





INCLUSIVE PION ASYMMETRY IN PROTON-PROTON COLLISIONS

C. Aidala SPIN 2008 Proceeding and CERN Courier June 2009



Working groups have been set up:

- Interim Steering Committee (13 members)
- Physics program
  - Theory (OV Teryaev)
  - Simulations (AP Nagaytsev, AV Guskov, SS Shimanskij)
  - Local polarimetry (VP Ladygin)
- Detector
  - Overall design (VA Anosov, IV Moshkovskij)
  - Magnet (AD Kovalenko)
  - Vertex detector (NI Zamjatin)
  - Tracking (TL Enik)
  - FEE - INFN Turin ?
  - Trigger & DAQ (AV Koulikov, VN Frolov, VM Slepnev, I. Konorov)
  - TOF-RPC - IHEP Protvino ?
  - ECAL - OP Gavrishchuk
  - Muon range system (GD Alekseev)
- Software (OV Rogachevski, A Tkachenko)

Roadmap (cont'd)

- Preparation of the Technical Design Report (2019 – 2020)
- Signing up of contracts for construction of the main detector systems: magnet, tracking system, muon range system, EM calorimeter, local polarimetry, trigger and DAQ system, etc. (2020);
- Construction of the detector (2021-2025)
- First measurements – 2025.

ПОЕХАЛИ!

DEUTERON STATIC PROPERTIES FROM NN-POTENTIALS

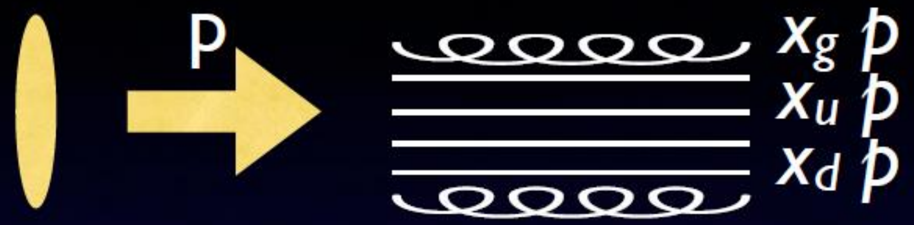
Таблица 1: Статические свойства дейтрона

	$E_D(MeV)$	$P_D(\%)$	$< r_D^2 >^{1/2} (fm)$	$Q(fm^2)$	$\eta = \frac{A_D}{A_S}$	$f_{\pi NN}^2$	$\mu_D(n.m)$
Exp.	2.224579(9)	–	1.9560(68)	0.2859(3)	0.0271(4)	0.0776(9)	0.857406(1)
MU	2.2246	6.78	1.9611	0.2860	0.0271	0.07745	0.843
Paris	2.2250	5.77	1.9716	0.2789	0.0261	0.078	0.853
RHC	2.2246	6.50	1.9602	0.2770	0.0259	0.0757	0.840
RSC	2.2246	6.47	1.9569	0.2796	0.0262	0.0757	0.843
Bonn	2.225	4.58	1.86	0.2856	0.0267	–	–

Table 1: Deuteron properties in the dressed bag model.

Model	E_d(MeV)	$P_D(\%)$	r_m(fm)	Q_d(fm^2)	$\mu_d\ (\mu_N)$	A_S(fm$^{-1/2}$)	$\eta(D/S)$
RSC	2.22461	6.47	1.957	0.2796	0.8429	0.8776	0.0262
Moscow 99	2.22452	5.52	1.966	0.2722	0.8483	0.8844	0.0255
Bonn 2001	2.224575	4.85	1.966	0.270	0.8521	0.8846	0.0256
DBM (1) $P_{\text{in}} = 3.66\%$	2.22454	5.22	1.9715	0.2754	0.8548	0.8864	0.0259
DBM (2) $P_{\text{in}} = 2.5\%$	2.22459	5.31	1.970	0.2768	0.8538	0.8866	0.0263
experiment	2.224575		1.971	0.2859	0.8574	0.8846	0.0263

PDF



$0<x<1$

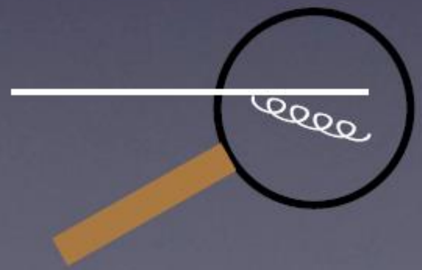
probability to find a "parton" *i* of momentum *x p*

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

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

Многокварковые конфигурации.
Как их можно увидеть и исследовать?

Правила кваркового счета

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

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

Предсказывалось, что для $p_{пучка} \geq 5$ ГэВ/с и углов $\theta_{см} > 40^o$

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

Здесь n_A, n_B, n_C и n_D число составляющих кварков в адронах A, B, C и D.

$s=(p_A+p_B)^2$ и $t=(p_A-p_C)^2$,

где P_X – четырех-импульсы адронов. Например:

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

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

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

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

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

SLAC-PUB-9281
July 2002

Perspectives on Exclusive Processes in QCD*

Stanley J. Brodsky

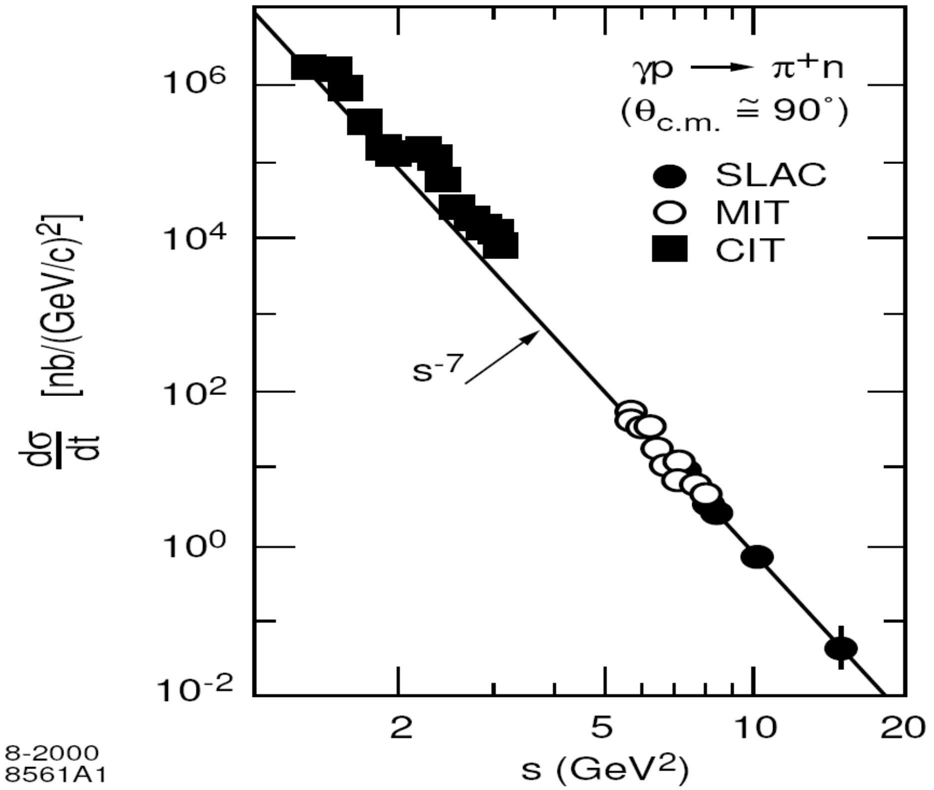


Figure 5: Comparison of photoproduction data with the dimensional counting power-law prediction. The data are summarized in Anderson *et al.*[70]

PHYSICAL REVIEW D VOLUME 49, NUMBER 1 1 JANUARY 1994

Comparison of 20 exclusive reactions at large t

TABLE I. Measured reactions presented in this paper. The reactions are written as (beam + target) → (spectrometer particle + side particle). Reactions 1, 2, 3, 17, and 18 were measured with either final-state particle in the spectrometer.

Meson-baryon reactions	
1	$\pi^+ p \to p\pi^+$
2	$\pi^- p \to p\pi^-$
3	$K^+ p \to pK^+$
4	$K^- p \to pK^-$
5	$\pi^+ p \to p\rho^+$
6	$\pi^- p \to p\rho^-$
7	$K^+ p \to pK^{*+}$
8	$K^- p \to pK^{*-}$
9	$K^- p \to \pi^-\Sigma^+$
10	$K^- p \to \pi^+\Sigma^-$
11	$K^- p \to \Lambda\pi^0$
12	$\pi^- p \to \Lambda K^0$
13	$\pi^+ p \to \pi^+\Delta^+$
14	$\pi^- p \to \pi^-\Delta^+$
15	$\pi^- p \to \pi^+\Delta^-$
16	$K^+ p \to K^+\Delta^+$
Baryon-baryon reactions	
17	$pp \to pp$
18	$\bar{p}p \to p\bar{p}$
19	$\bar{p}p \to \pi^+\pi^-$
20	$\bar{p}p \to K^+K^-$

TABLE V. The scaling between E755 and E838 has been measured for eight meson-baryon an 2 baryon-baryon interactions at $\theta_{\text{c.m.}} = 90°$. The nominal beam momentum was 5.9 GeV/c and 9. GeV/c for E838 and E755, respectively. There is also an overall systematic error of $\Delta n_{\text{syst}} = \pm 0.$ from systematic errors of ±13% for E838 and ±9% for E755.

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

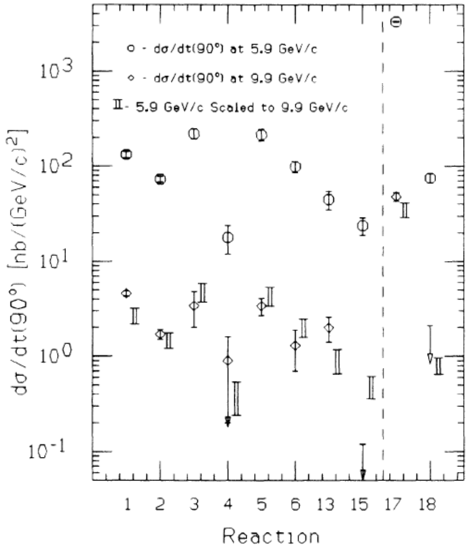


FIG. 26. The scaling between E755 and E838 has been calculated for eight meson-baryon and 2 baryon-baryon interactions at $\theta_{\text{c.m.}} = 90°$. The beam momentum for E838 was 5.9 GeV/c, corresponding to $s = 11.9$ GeV^2 for meson-baryon reactions and $s = 12.9$ GeV^2 for baryon-baryon reactions. For the 9.9 GeV/c momentum of E755, the corresponding values of s are 19.6 and 20.5 GeV^2.

SLAC – PUB – 4749
October 1988
(M)

ANTIPROTON ANNIHILATION IN QUANTUM CHROMODYNAMICS*

STANLEY J. BRODSKY

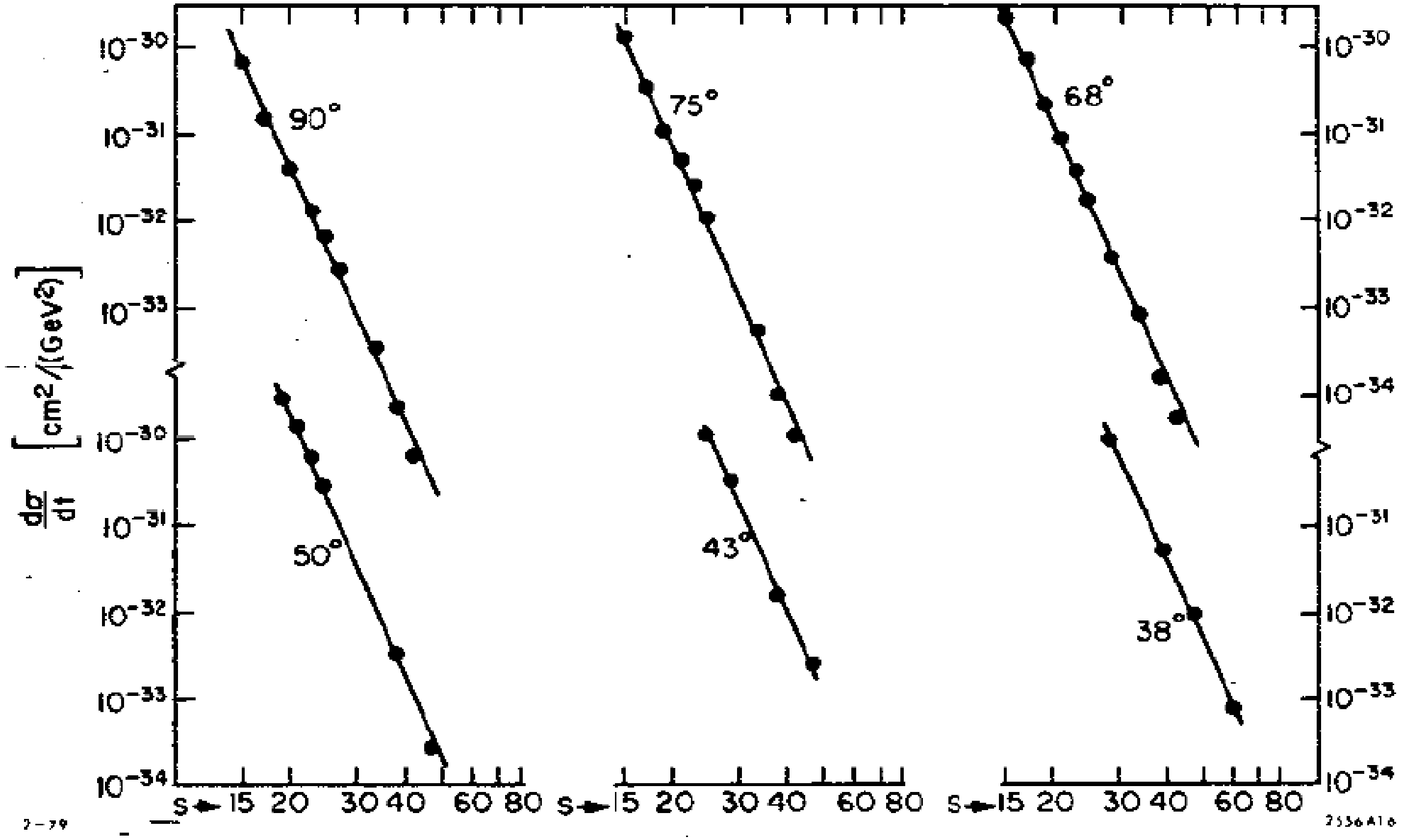


Fig. 16. Test of fixed θ_{CM} scaling for elastic pp scattering. The best fit gives the power $N = 9.7 \pm 0.5$ compared to the dimensional counting prediction $N=10$. Small deviations are not readily apparent on this log-log plot. The compilation is from Landshoff and Polkinghorne.

«ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА»,
1984, ТОМ 15, ВЫП. 6

УДК 539.12.172

МНОГОКВАРКОВЫЕ СИСТЕМЫ В ЯДЕРНЫХ ПРОЦЕССАХ

В. В. Буров, В. К. Лукьянов, А. И. Титов

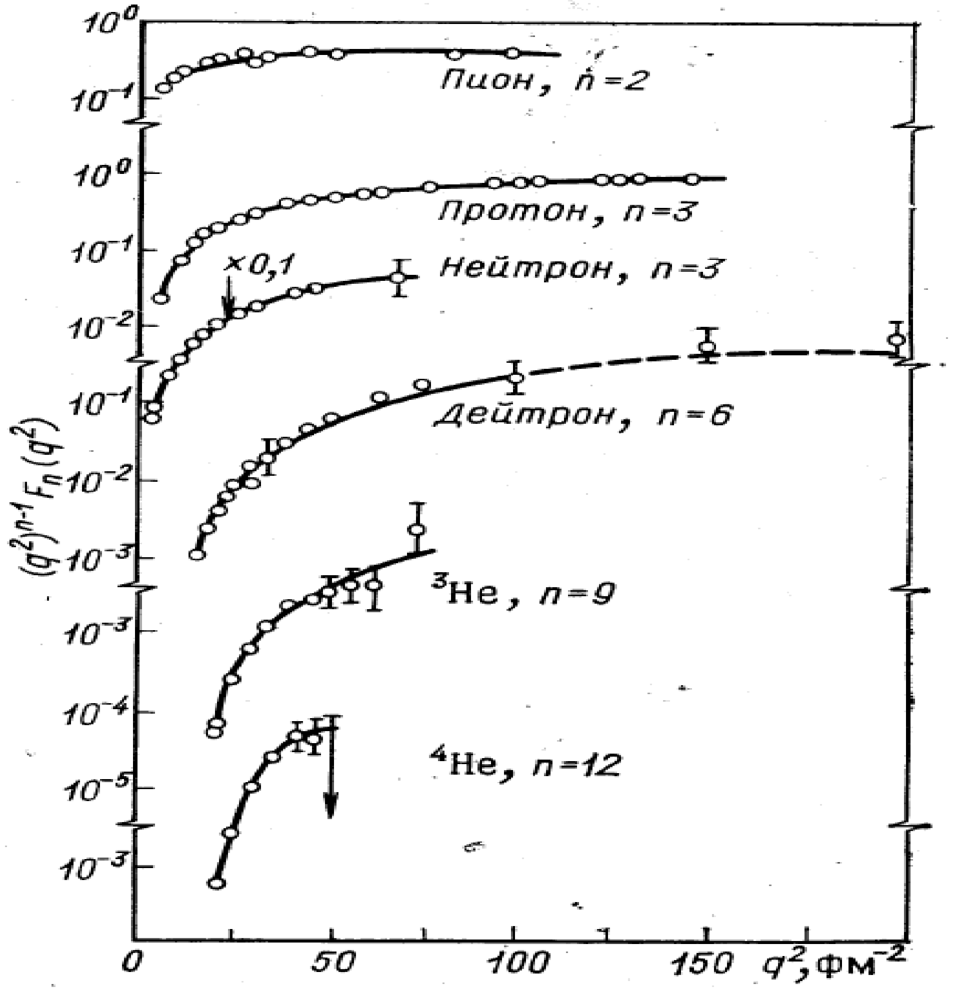


Рис. 5. Зависимость экспериментальных упругих формфакторов пиона, протона, нейтрона, дейтрона, ядер ^{3}He, ^{4}He [20, 21], умноженных на $(q^2)^{n-1}$, от q^2. Линии проведены по точкам

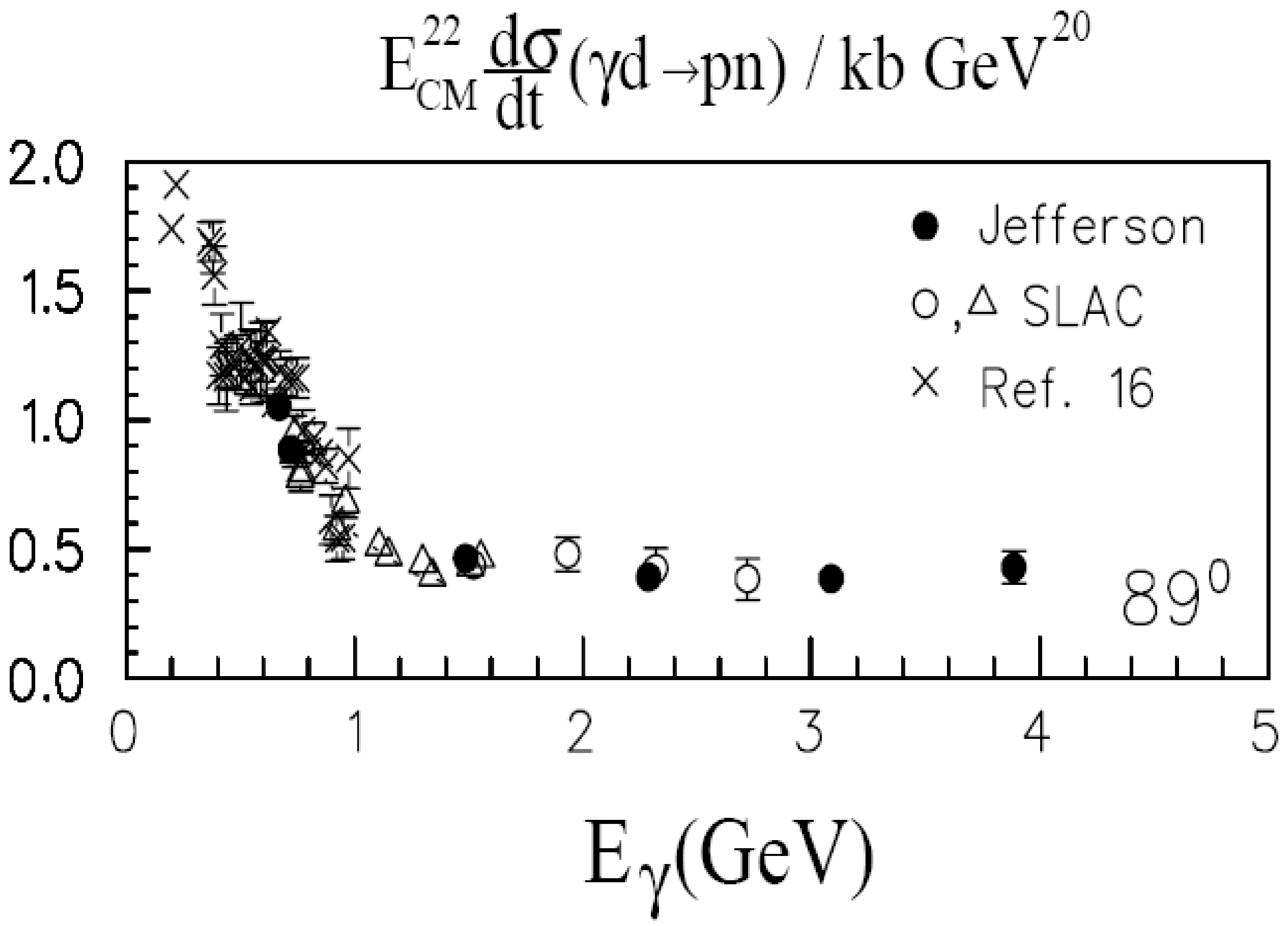
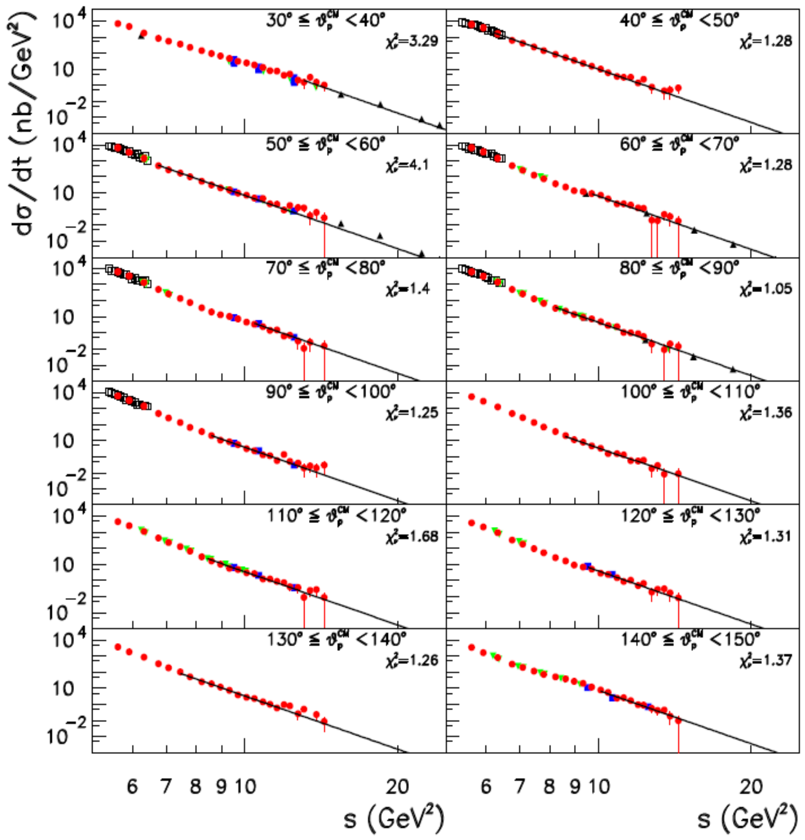


Fig. 1: Large angle γ-disintegration of a deuteron [28].

Light-Front QCD*

Stanley J. Brodsky

SLAC–PUB–10871
November 2004



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

constant at fixed CM angle

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

Eur. Phys. J. A 8, 423–428 (2000)

THE EUROPEAN PHYSICAL JOURNAL A

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

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

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

Received: 3 April 2000 / Revised version: 22 May 2000
Communicated by B. Povh

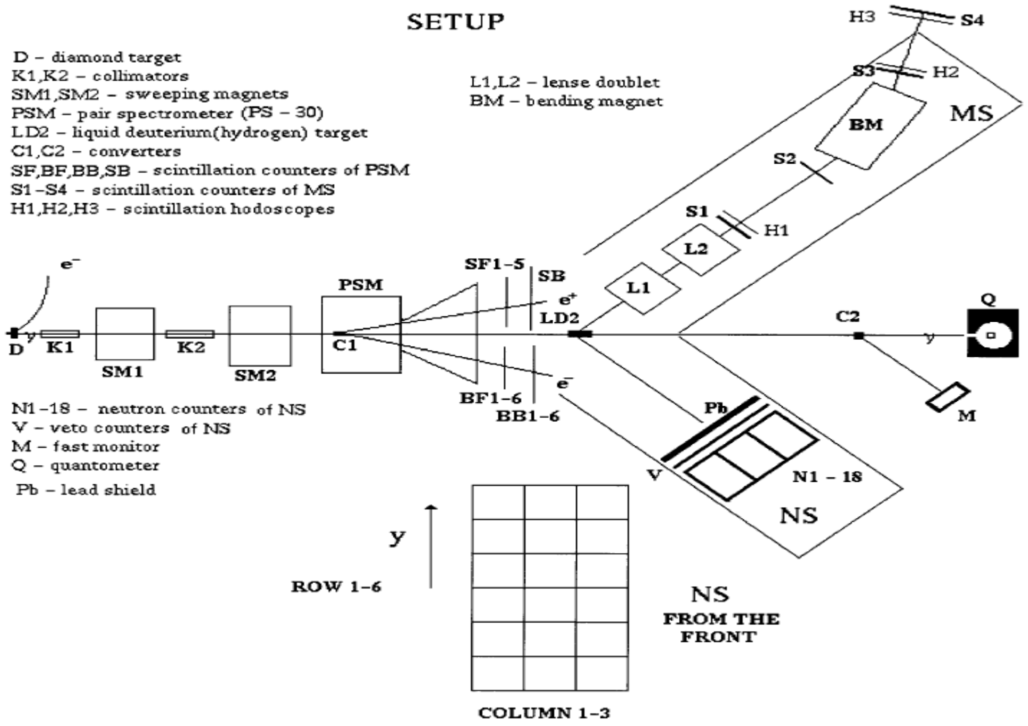


Fig. 2. Experimental Setup. In the frame, the neutron spectrometer NS-18 from the front.

$$\Sigma(\theta) = (d\sigma_{||} - d\sigma_T)/(d\sigma_{||} + d\sigma_T)$$

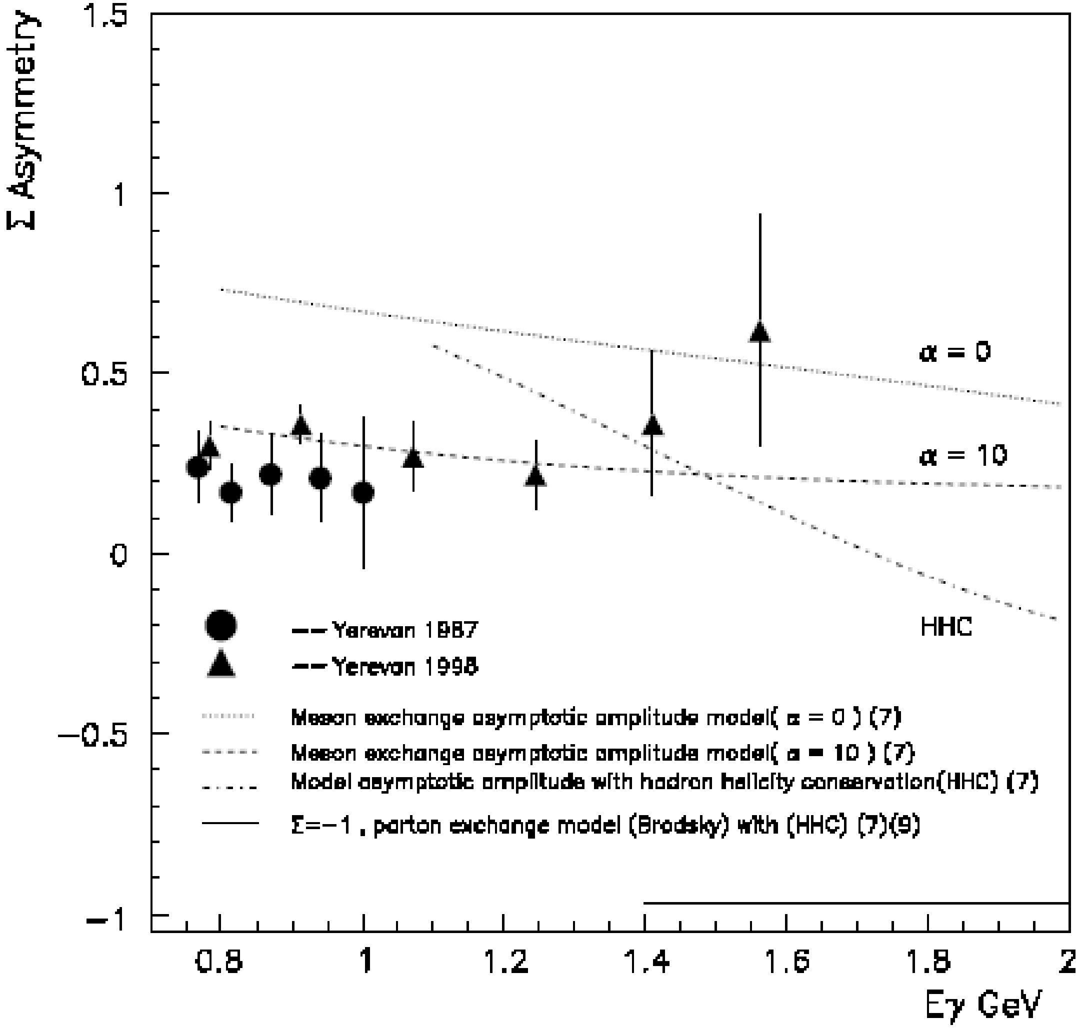


Fig. 8. The energy dependence of the cross-section asymmetry Σ for $\theta_p = 90°$ in the cms.

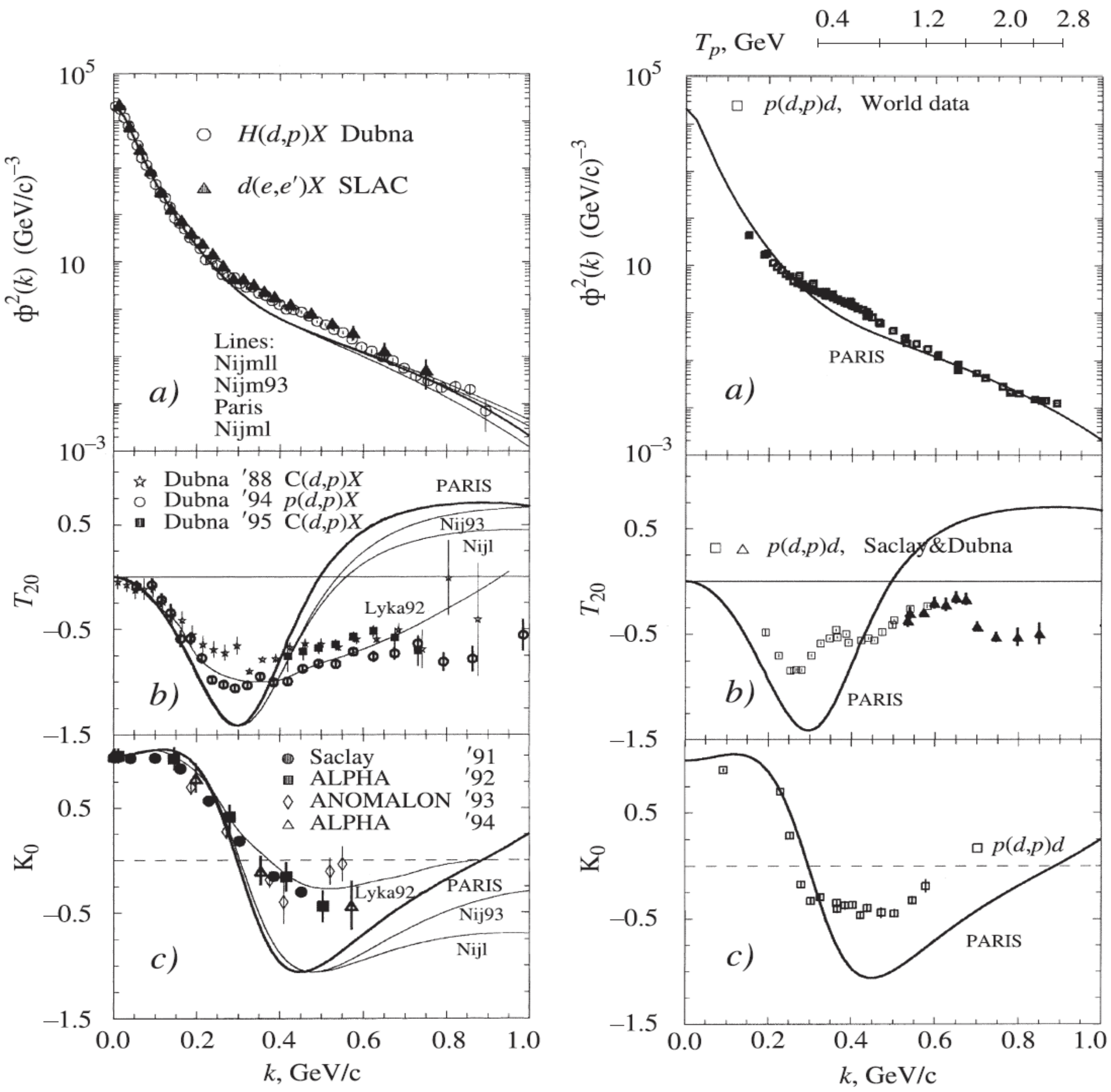


Рис. 5. Сводка данных экспериментов по фрагментации (слева) и упругому рассеянию «назад» (справа) поляризованных и неполяризованных дейтронов

Pis'ma v ZhETF, vol. 81, iss. 7, pp. 387 – 390

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

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

Submitted 11 January 2005
Resubmitted 28 February 2005

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

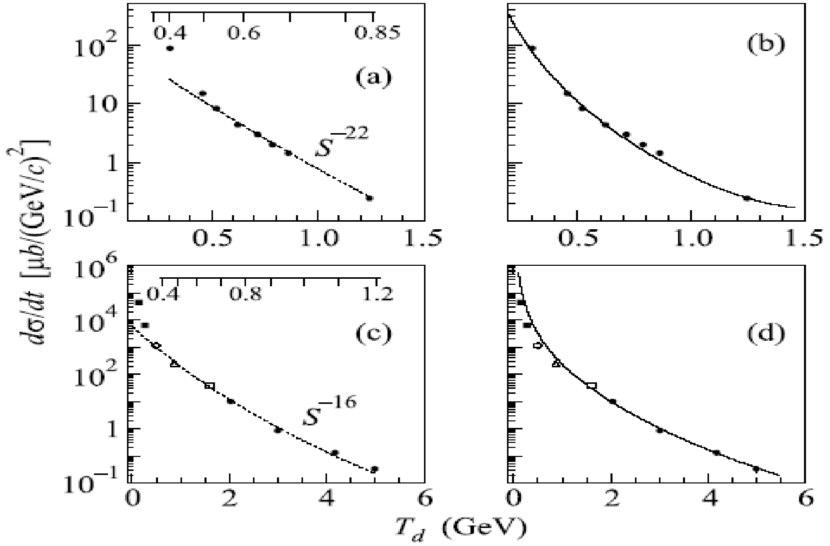


Fig.2. The differential cross section of the $dd \to n^3$He and $dd \to p^3$H reactions at $\theta_{cm} = 60^o$ (a), (b) and $dp \to dp$ at $\theta_{cm} = 127^o$ (c), (d) versus the deuteron beam kinetic energy. Experimental data in (a), (b) are taken from [20]. In (c), (d), the experimental data (black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

Где видны указания на подструктуру в нуклонах и ядрах?

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 $(q\,q\,q)$, $(q\,q\,q\,q\,\bar{q})$, etc., while mesons are made out of $(q\,\bar{q})$, $(q\,q\,\bar{q}\,\bar{q})$, etc. It is assuming that the lowest baryon configuration $(q\,q\,q)$ 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.

Reviews of Modern Physics, Vol. 65, No. 4, October 1993

Diquarks

Mauro Anselmino and Enrico Predazzi

Dipartimento di Fisica Teorica, Università di Torino and Istituto Nazionale di Fisica Nucleare, Sezione di Torino, I-10125 Torino, Italy

Svante Ekelin

Department of Mathematics, Royal Institute of Technology, S-100 44 Stockholm, Sweden

Sverker Fredriksson

Department of Physics, Luleå University of Technology, S-97187 Luleå, Sweden

D. B. Lichtenberg

Department of Physics, Indiana University, Bloomington, Indiana 47405

Among the useful phenomenological ideas is the notion of a diquark. Gell-Mann (1964) first mentioned the possibility of diquarks in his original paper on quarks. Later, Ida and Kobayashi (1966) and Lichtenberg and Tassie (1967) introduced diquarks in order to describe a baryon as a composite state of two particles, a quark and diquark. Around the same time, states having some or all of the quantum numbers of diquarks were introduced in certain group-theoretical schemes by Bose (1966), Bose and Sudarshan (1967), and Miyazawa (1966, 1968).

Aside from questions of principle, lattice calculations suffer because an enormous amount of computer time is necessary to achieve very modest results. Thus, at present, calculations with lattice gauge theory are not a satisfactory substitute for calculations with phenomenological models.

Are There Diquarks in the Nucleon?

arXiv:hep-ph/0410304 v3 23 May 2005

M. Cristoforettia b, P. Facciolia c, G. Ripkaa d, and M. Trainia

We study in detail the physical properties of the 0+ diquark, using the Random Instanton Liquid Model. We find that instanton forces are sufficiently strong to form a diquark bound-state, with a mass of ~ 500 MeV, which is compatible with earlier estimates. We also compute its electro-magnetic form factor and find that the diquark is a broad object, with a size comparable with that of the proton.

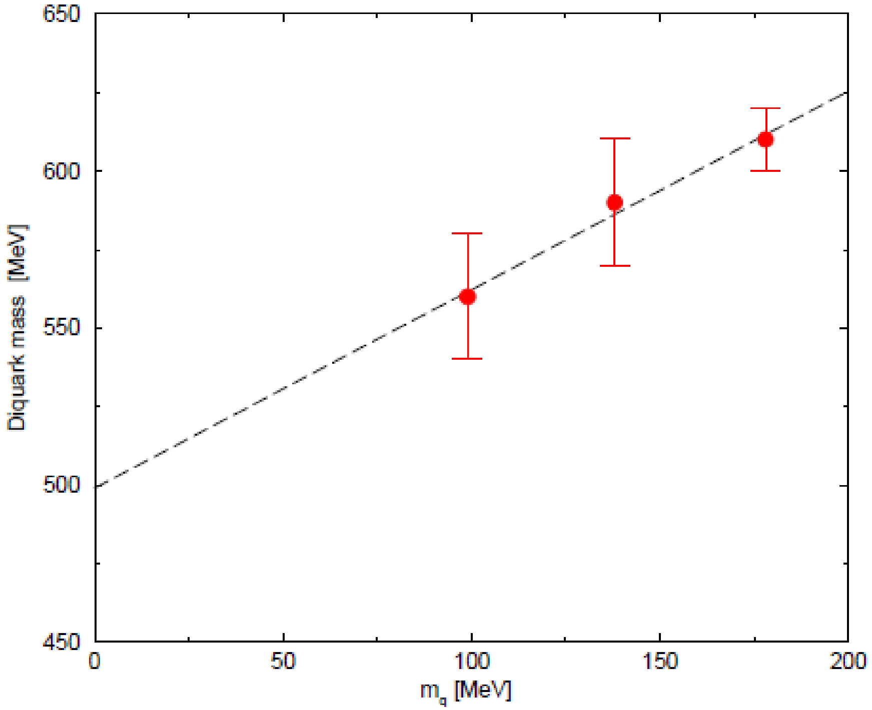


FIG. 6: The mass of the u-d diquark, computed in the Random Instanton Liquid Model, as a function of the u and d bare quark mass.

ЯДЕРНАЯ ФИЗИКА, 2011, том 74, № 3, с. 438–446

ЭЛЕМЕНТАРНЫЕ ЧАСТИЦЫ И ПОЛЯ

QUARK–DIQUARK SYSTEMATICS OF BARYONS: SPECTRAL INTEGRAL EQUATIONS FOR SYSTEMS COMPOSED BY LIGHT QUARKS

A. V. Anisovich, V. V. Anisovich*,
M. A. Matveev, V. A. Nikonov, A. V. Sarantsev, T. O. Vulfs
Petersburg Nuclear Physics Institute, Russian Academy of Sciences, Gatchina
Received May 7, 2010; in final form, August 30, 2010

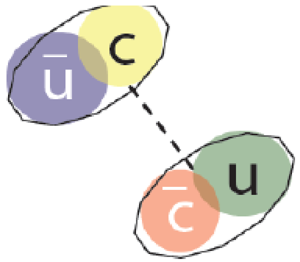
How Often Do Diquarks Form? A Very Simple Model

Richard F. Lebed*
Department of Physics, Arizona State University, Tempe, Arizona 85287-1504, USA
(Dated: June, 2016)

Starting from a textbook result, the nearest-neighbor distribution of particles in an ideal gas, we develop estimates for the probability with which quarks q in a mixed q, $\bar{q}$ gas are more strongly attracted to the nearest q, potentially forming a diquark, than to the nearest $\bar{q}$. Generic probabilities lie in the range of tens of percent, with values in the several percent range even under extreme assumptions favoring $q\bar{q}$ over qq attraction.

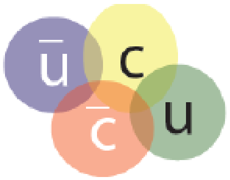
We have seen that the large relative size of the short-distance attraction between quarks in the color-antitriplet channel compared to the attraction between a quark and an antiquark in the color-singlet channel leads inexorably to a given quark being initially attracted to a quark rather than an antiquark a sizeable fraction of the time. We interpret this initial attraction as the seed event in the formation of a compact diquark qq rather than a color-singlet $q\bar{q}$ pair.

Tetraquarks (X, Y, Z)



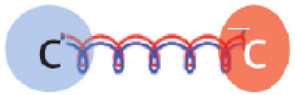
Molecular states:

- Loosely bound states of a pair of mesons,
- bound by the long-range color-singlet pion exchange,
- weakly bound, mesons tend to decay as if they were free.



Tetraquarks:

- bound states of four quarks,
- bound by colored-force between quarks,
- decay through rearrangement,
- many states with the same multiplet, some are with non-zero charge, or strangeness



Hybrids:

- bound states with a pair of quarks and one excited gluon
- Lattice and model predictions for lowest lying charmonium hybrid m~4200 MeV

Status of the pentaquark problem

- 1^{st} 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 !)

DIQURK DYNAMIC

Kim V.T. E2-87-75

Diquarks as a Source of Large-$P_\perp$ Baryons in Hard Nucleon Collisions

The production of nucleons, symmetric nucleon pairs, and Λ^0-hyperons with large $p_\perp$ in pp-collisions is discussed in the framework of a dominatiing scalar (ud)-diquark nucleon model. The necessity of making allowance for higher twists-diguarks for explaining strong scaling breaking in p/π^+ ratio is shown. The approximate equation $\Lambda/p \simeq k^+/\pi^+$ is predicted in this model.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1987

Diquarks

V.T. Kim (1987)

pp -> p+X, pp -> pp+X

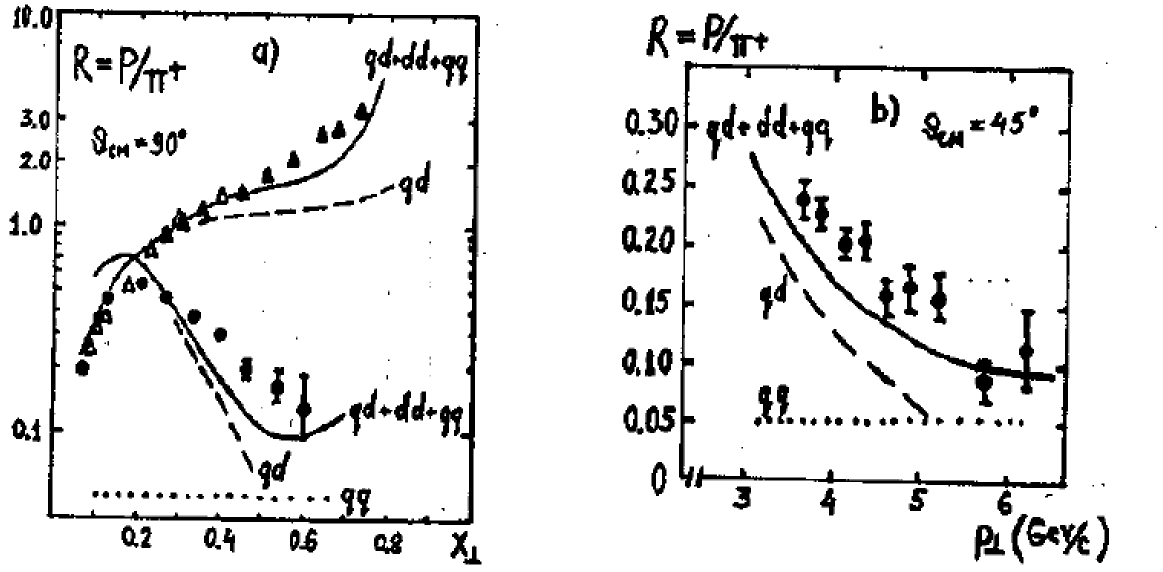


Fig. 1. $R=P/\pi^+$ -ratio in pp-collisions. a) $\vartheta_{cM}=90^\circ$: ● – FNAL data /16/ at $\sqrt{s}=23.4$ GeV (E_L = 300 GeV); △ , ▲ – IHEP (Serpukhov) data/19,20/ at $\sqrt{s}$ = 11.5 GeV (E_L = 70 GeV). b) $\vartheta_{cM}=45^\circ$: ● – ISR CERN data /18/ at $\sqrt{s}$ = 62 GeV ($E_L \simeq$ 1900 GeV).

The result of calcuations of $pp \to ppX$ processes/29/ (symmetric -proton-pair production) according to the formula in work/30/ for the double inclusive cross section, which in general must be applied carefully/31/ , is shown in Fig.2. The main contribution to the cross section of production of proton pairs with transverse momenta opposite and equal in values is given by diquark-diquark scattering.

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

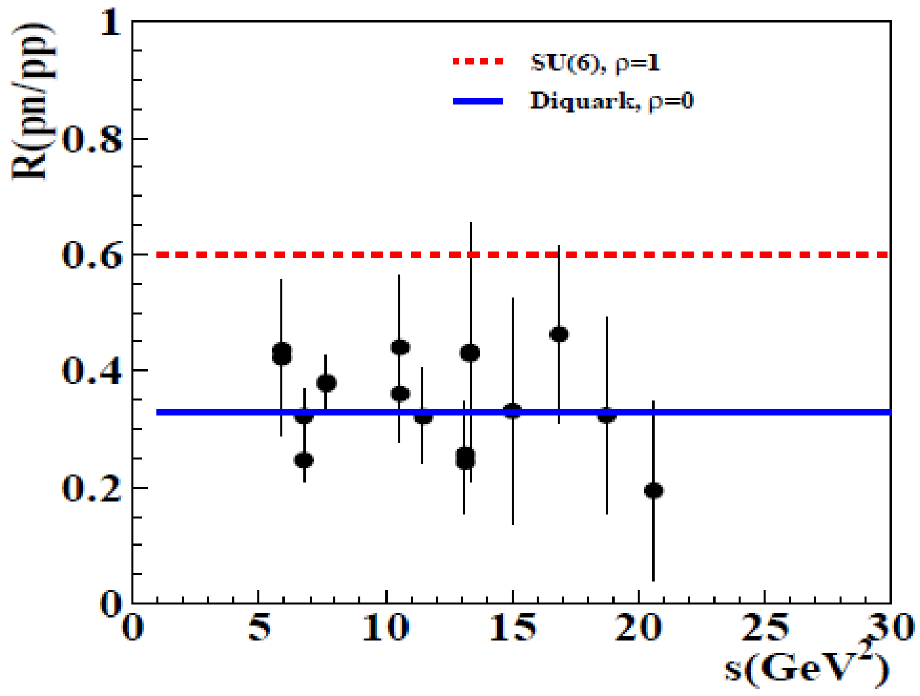


FIG. 2: (Color online) Ratio of the $pn \to pn$ to $pp \to pp$ elastic differential cross sections as a function of s at $\theta^N_{c.m.} = 90^0$.

РЯФ

Какие состояния у ядерной материи могут быть?

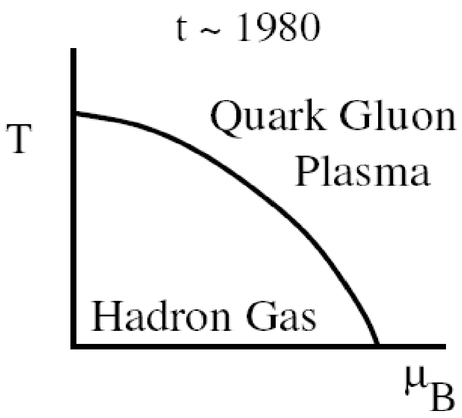
RHIC Physics: 3 Lectures*

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

September 13, 2003

+ CERN Yellow Report 2007-005, p.75

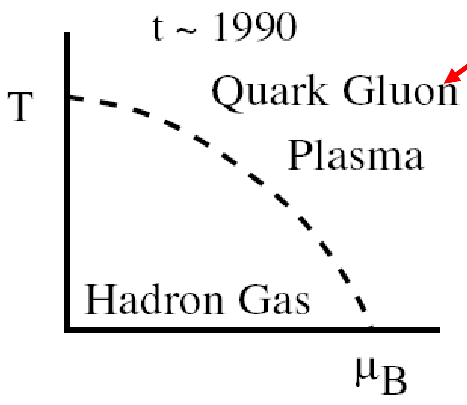
The Evolving QCD Phase Transition

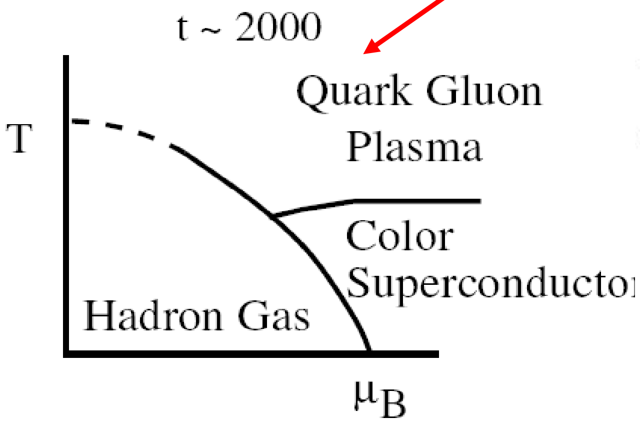


Critical Temperature 150 - 200 MeV ($\mu_B = 0$)
Critical Density 1/2-2 Baryons/Fm^3 ($T = 0$)

SPS Time (CERN)

RHIC Time(BNL)





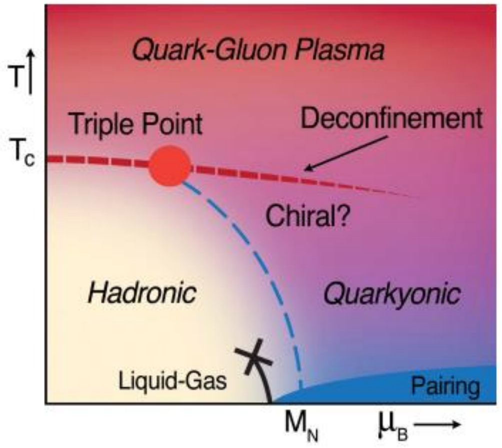
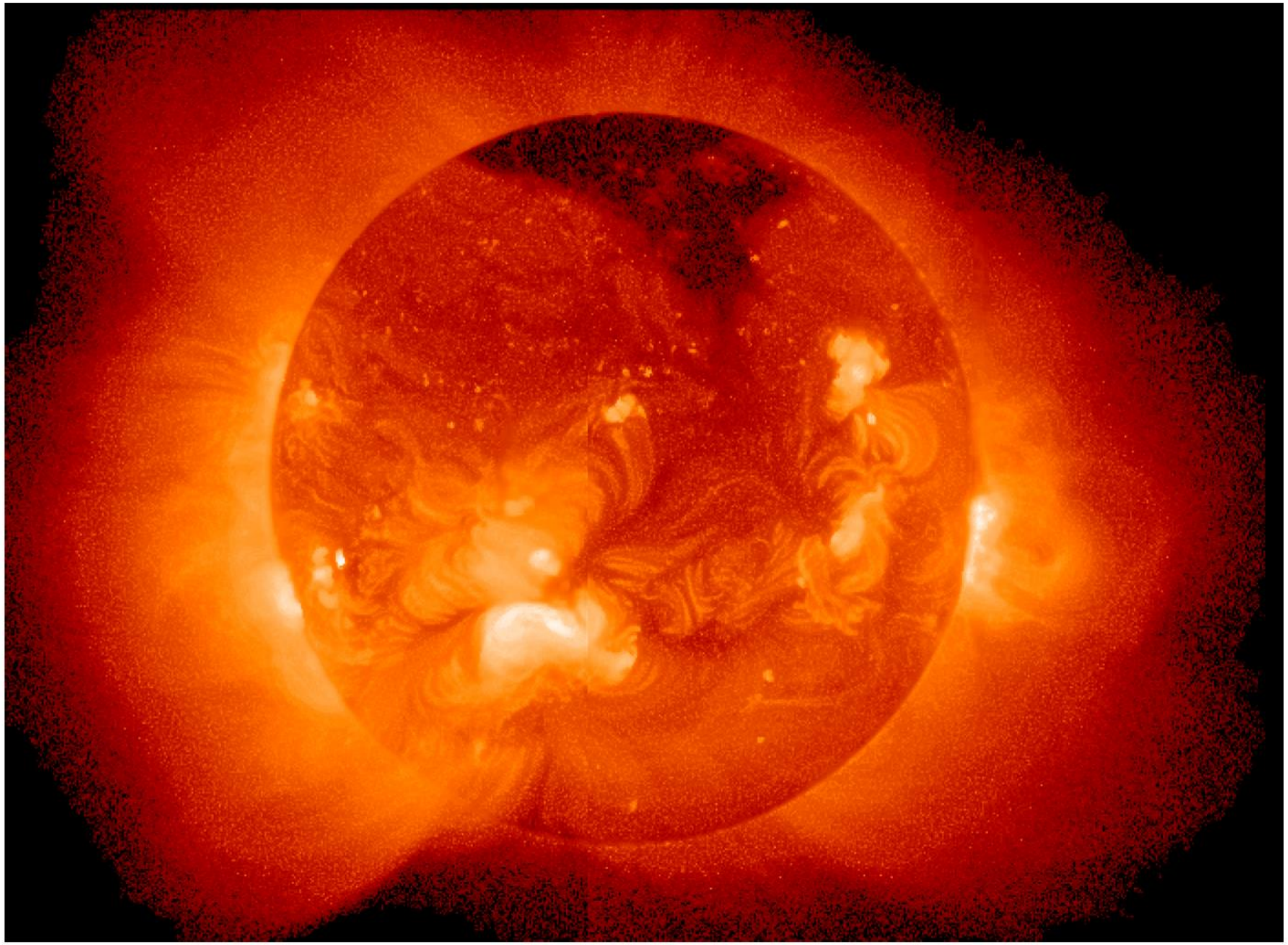


Figure 4: A phase diagram for QCD collisions.

Temperature at the centre of the Sun ~ 15 000 000 K

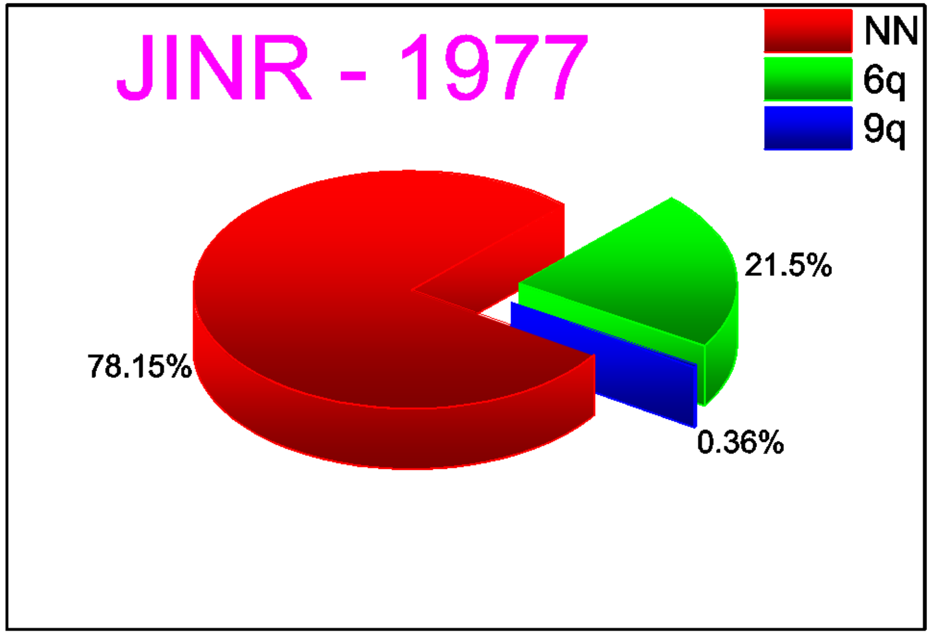


A medium of 170 MeV is more than 100 000 times hotter !!!

^{12}C - structure

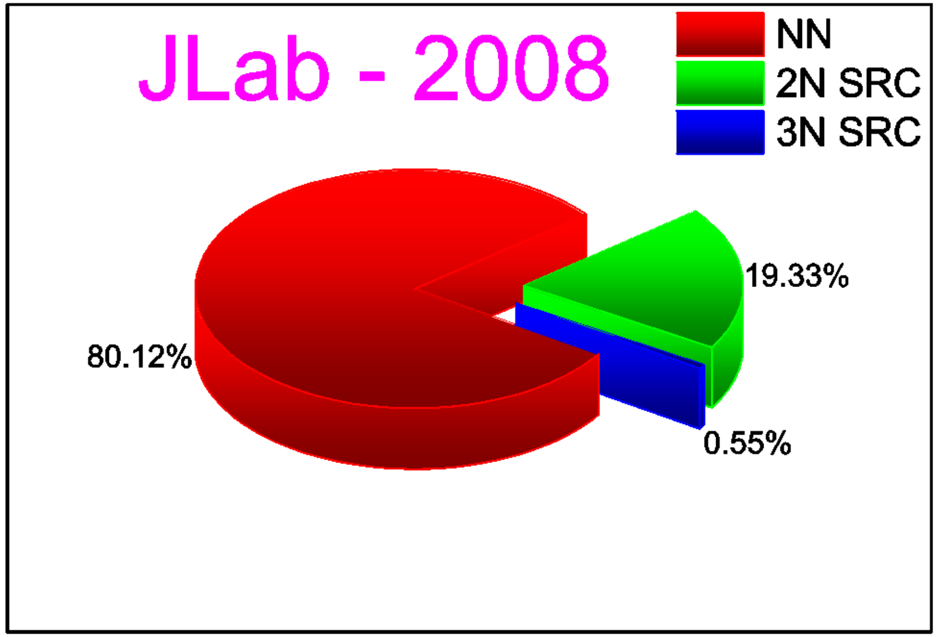
RNP - program at JINR

V.V.Burov, 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]



38

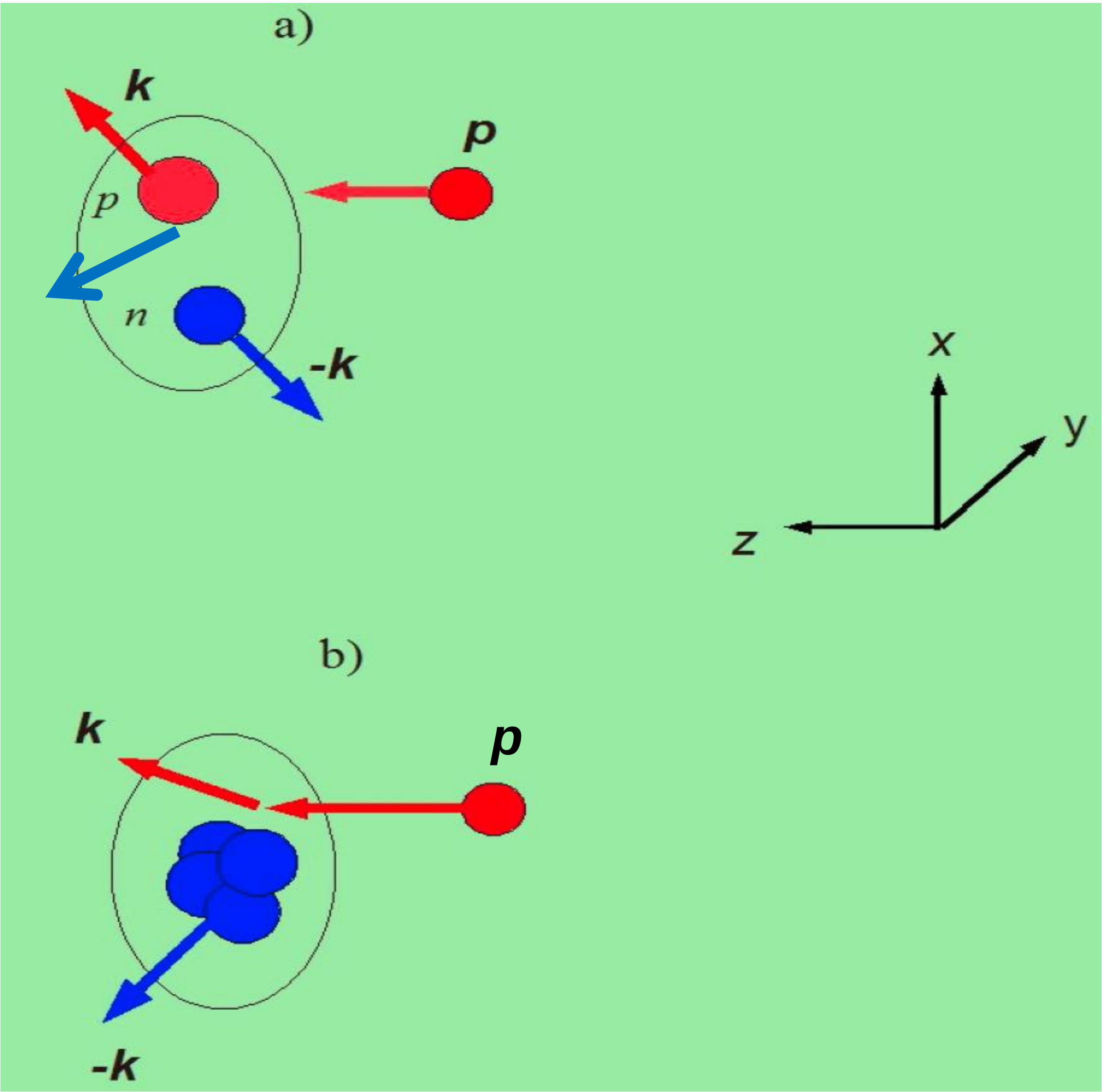
Нам необходимо ответить на вопрос:

- есть ли многонуклонные(многокварковые) состояния в обычной ядерной материи или реализуется сценарий SRC ?

Knot out cold dense nuclear configurations

SRC configuration

Multiquark configuration



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)

A mass analysis has been made of the relatively low momentum particles emitted from Al and Be targets when struck by 30- and 33-Bev protons. Measurements were made at 90°, 45°, and $13\frac{1}{4}$° relative to the direction of the Brookhaven AGS proton beam. Magnetic deflection and time-of-flight technique were used to determine the mass of the particles.

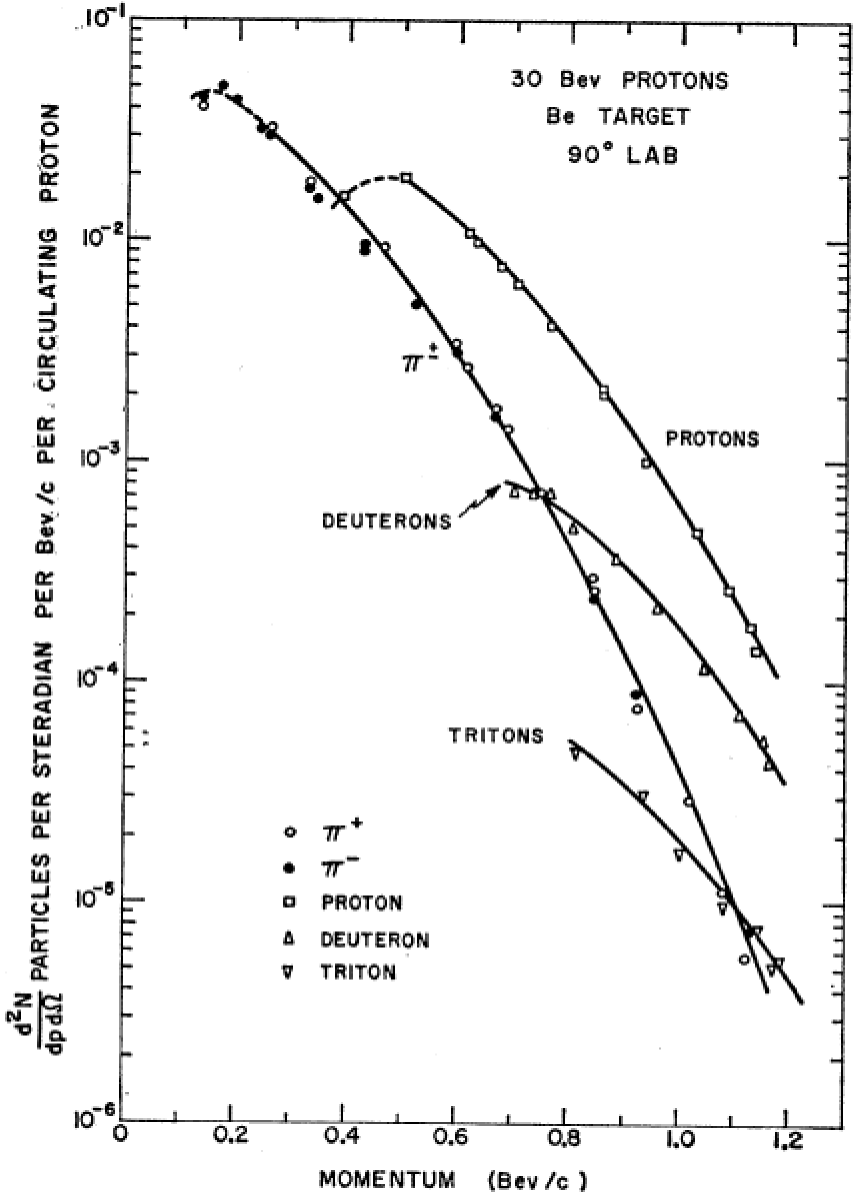
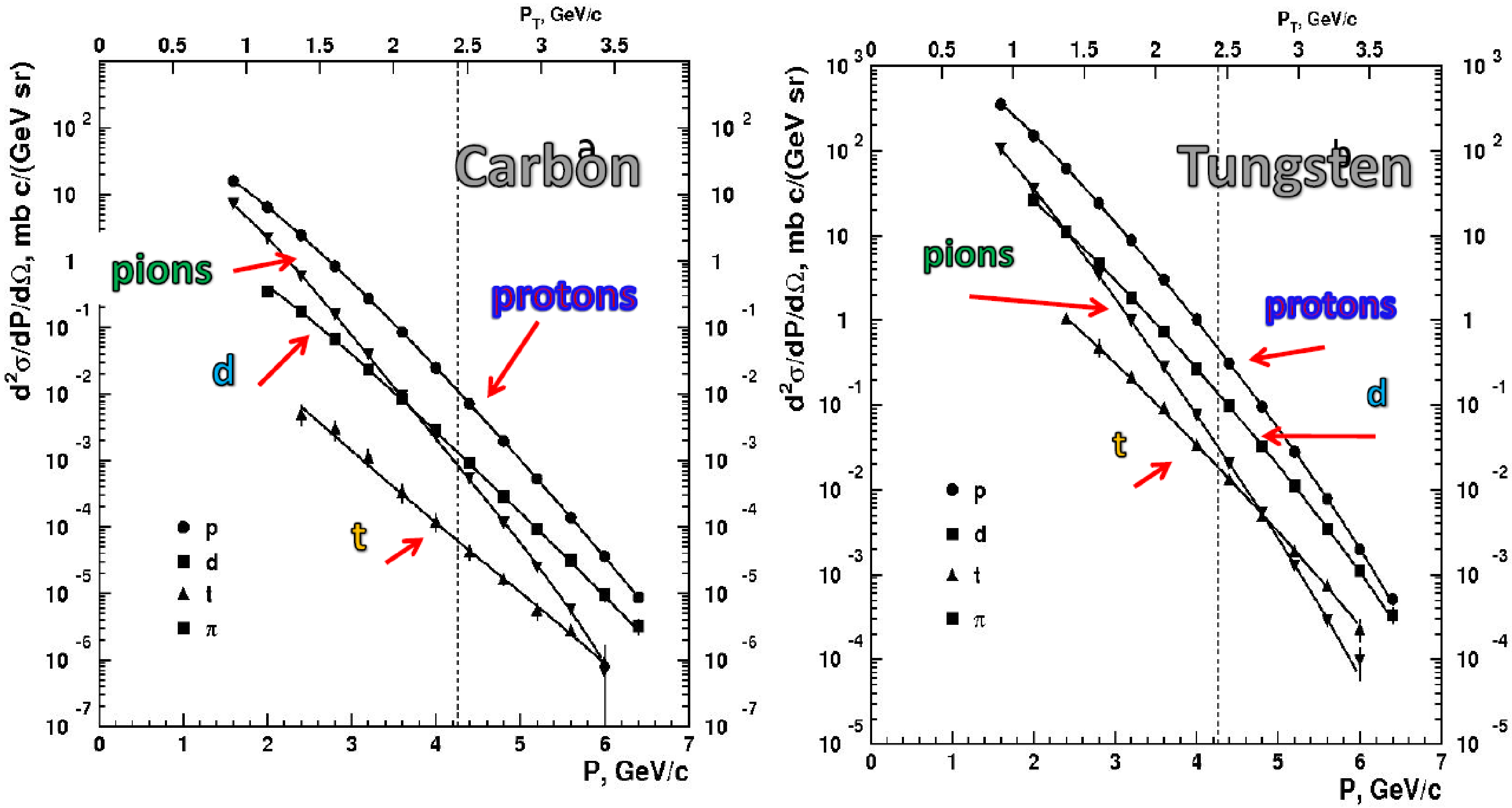


FIG. 2. Momentum spectrum of particles emitted at 90° from a beryllium target struck by 30-Bev protons. The ordinate is the number of particles produced at the target per steradian per Bev/c per circulating proton. The dashed portions of the curves indicate regions where the corrections due to multiple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

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



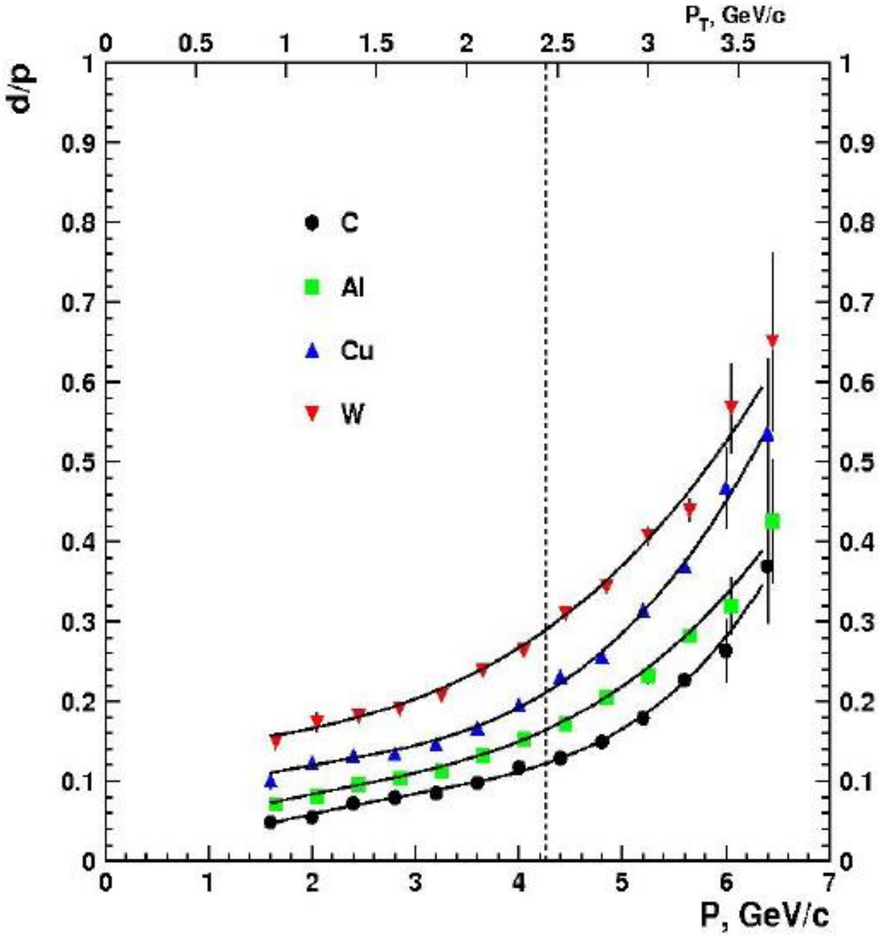
Invariant function found for positive pion, proton, deuteron and triton.

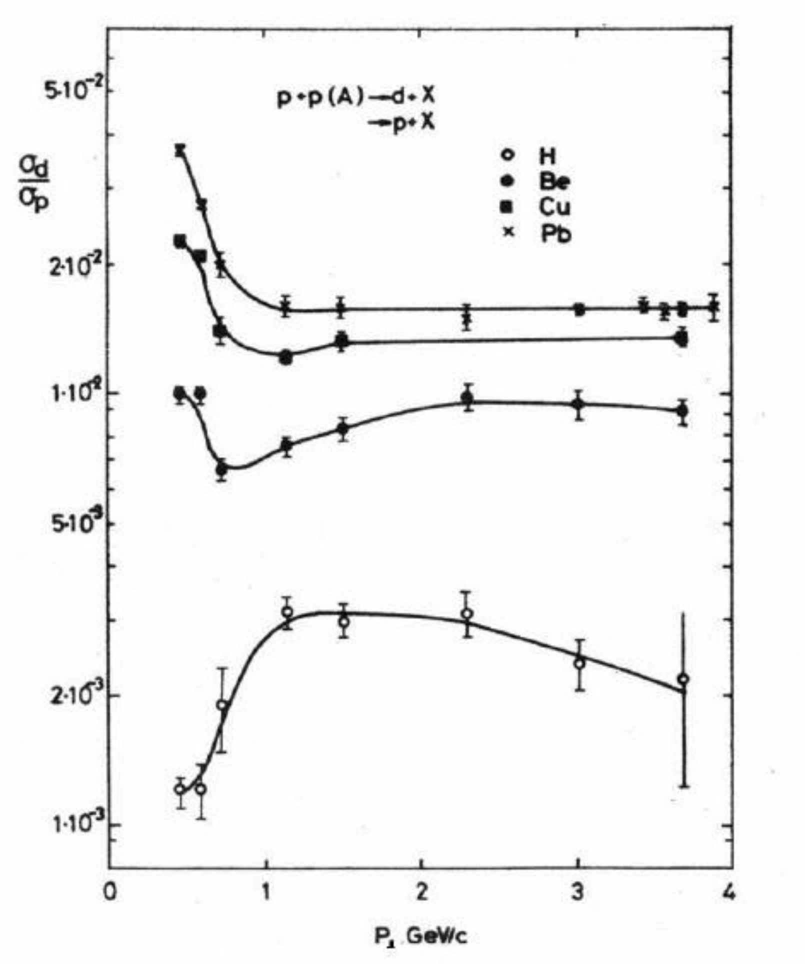
The vertical dashed lines indicate the kinematical limit for elastic nucleon–nucleon scattering. The upper horizontal scale shows values of the transverse momentum p_T *.*

Ratio d/p

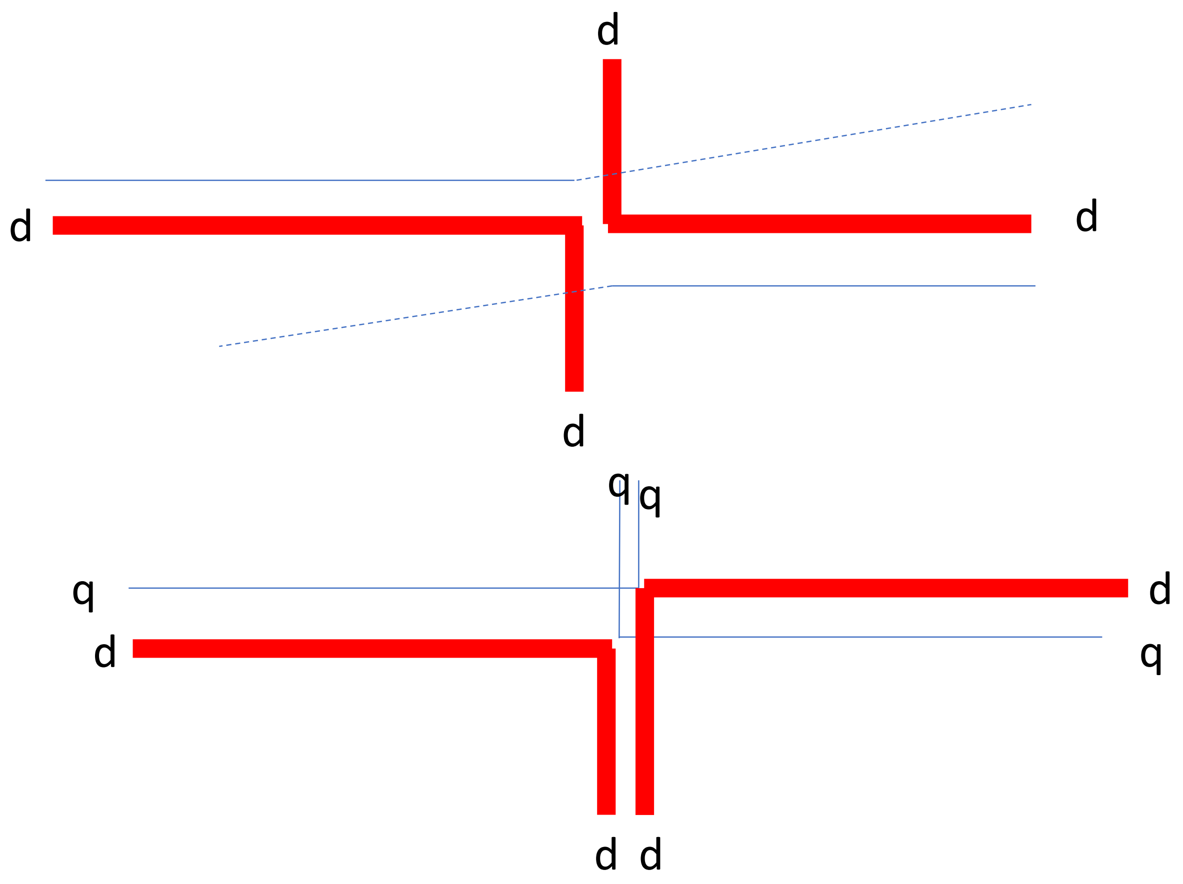
SPIN data

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





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



Kim's mechanisms

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.

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]

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

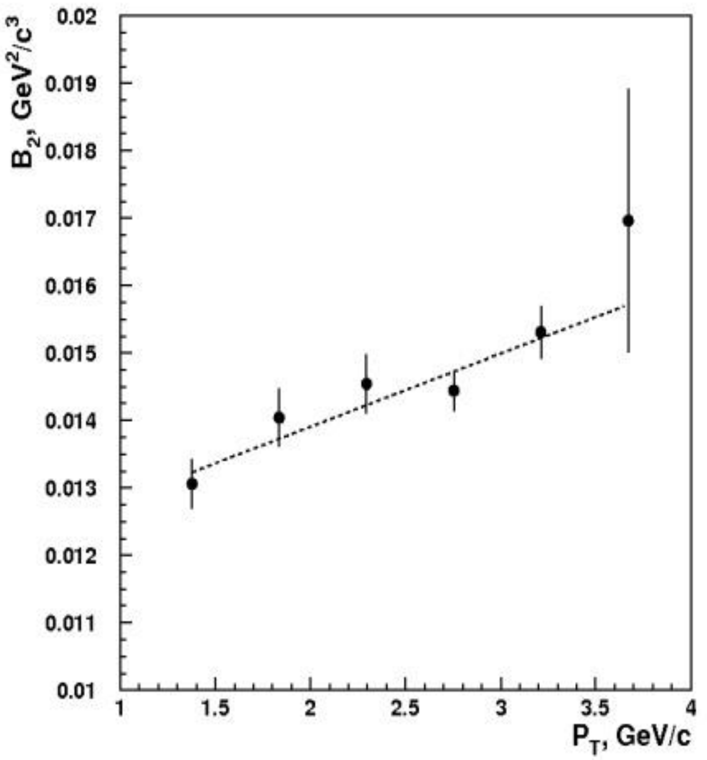
Mean values of the B_2 parameter

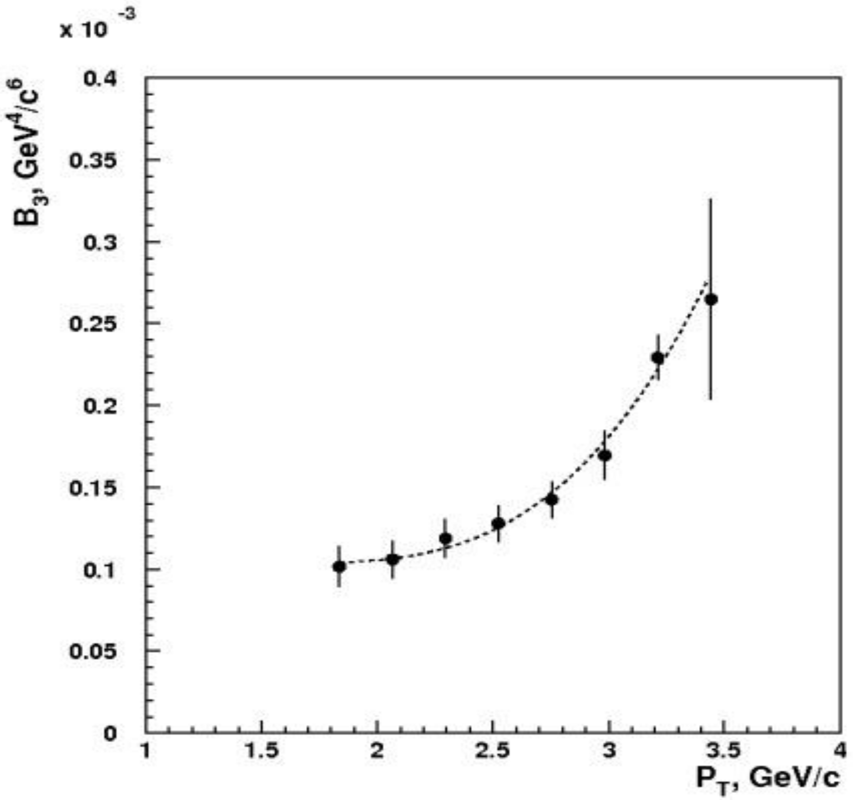
Target	C	Al	Cu	W
$B_2 \times 10^2$, GeV$^2/c^3$	1.41 ± 0.10	1.56 ± 0.08	1.51 ± 0.07	1.41 ± 0.06

SPIN data

$$B_2 \sim V^{-1}$$

$$B_3 \sim V^{-2})$$





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).

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

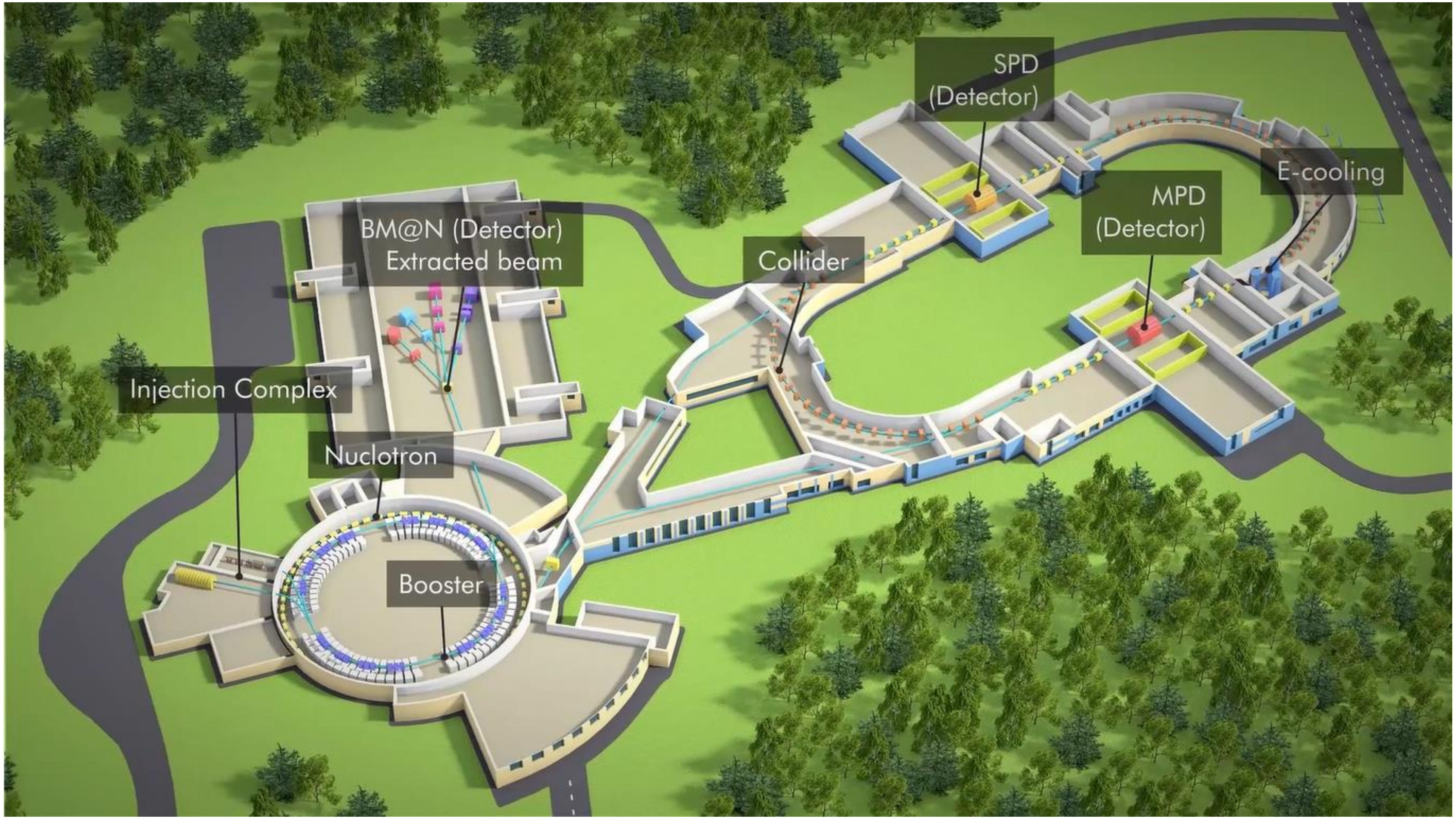
The effect of a concept-driven revolution is to explain old things in new ways.

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

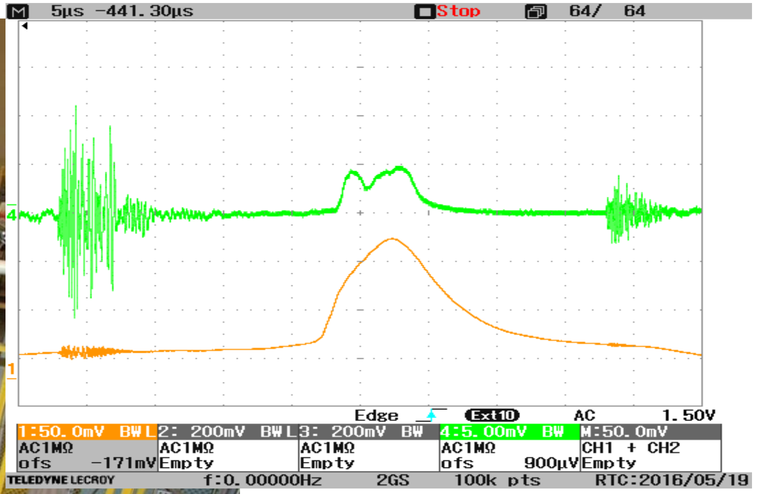
From Freeman Dyson 'Imagined Worlds'

The tools

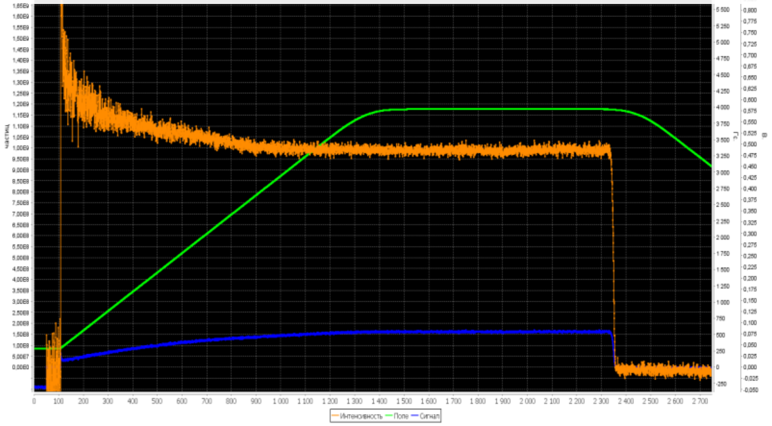
NICA project
new design & conception



New for-injector LU-20 & SPI



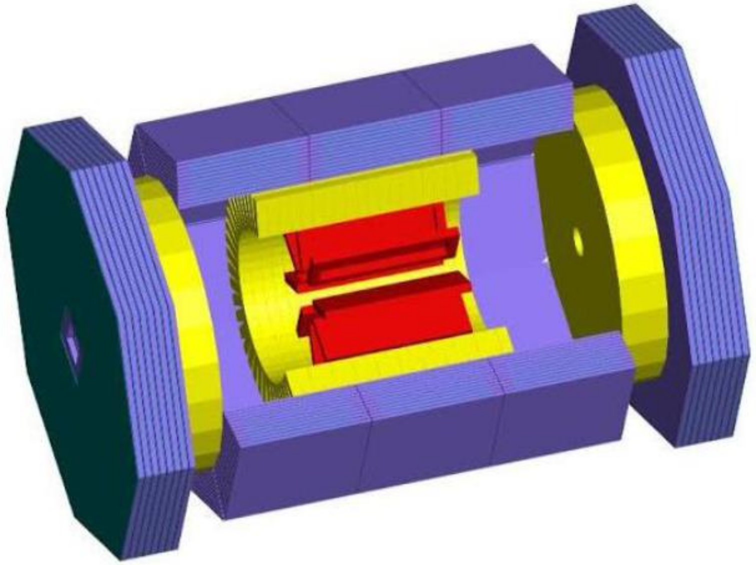
RUN #52, d+
Energy 750 MeV/u, intensity 10^9

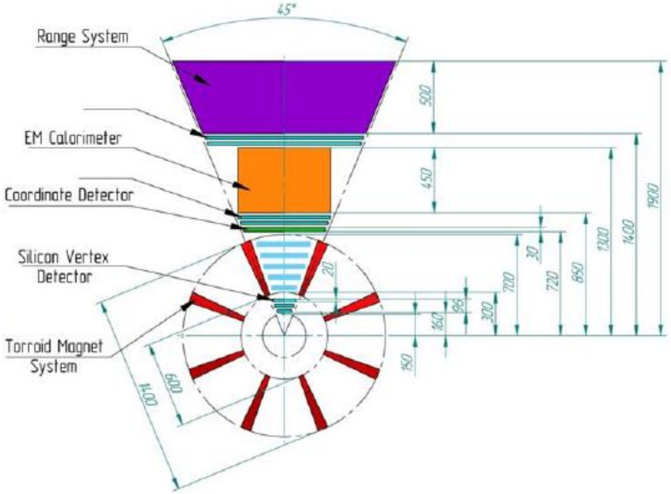


May 16 2016: 1st beam in LU-20
June 12 2016: 1st beam from the SPI

Possible layout of the SPD.

Установка может состоять из 3-х основных частей: баррельной и двух торцевых.
Длина установки – около 6 м, диаметр – до 4 м.





Показаны основные детекторы установки:
красным – торроидальный магнит,
желтым – электромагнитный калориметр,
мюонная система - выделена синим цветом.

Работа на NICA со спин-флипперами

а) новый режимы заполнение колец (все банчи с одной поляризацией в обоих кольцах) и работы (поочерёдное включение спин-флипперов в кольцах):

1-е кольцо +++... |xxx| - - -... |----| - - -... |xxx| +++ |----| +++...

1-е кольцо +++... |----| +++... |xxx| - - -... |----| - - - |xxx| +++...

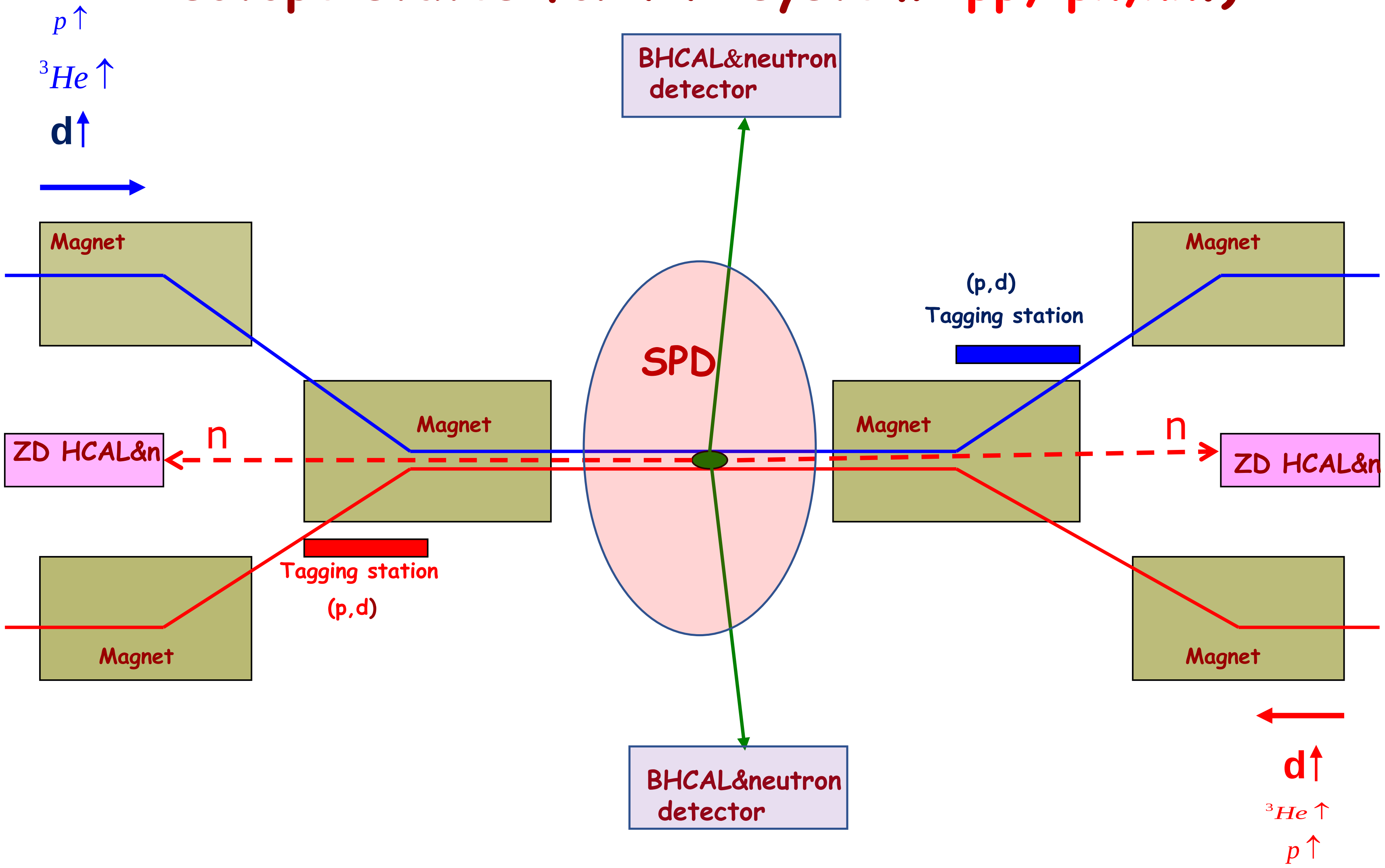
(+ +) (- +) (- -) (+ -) (+ +)

|xxx| - ротатор включён, нет набора данных

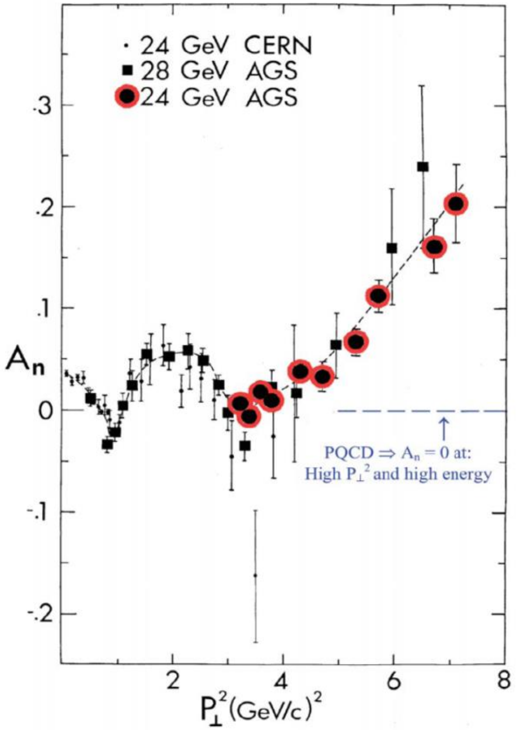
|----| - ротатор не включён, нет набора данных

б) нет проблемы измерения межбанчивой светимости, нет проблемы с разной поляризацией в разных модах при работе источника!

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!



AGS 1985-1990 A_n

PERTURBATIVE QCD ⇒

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

$A_n \neq 0$ ⇒

PROBLEM with PQCD?

NO MODEL can EXPLAIN ALL

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

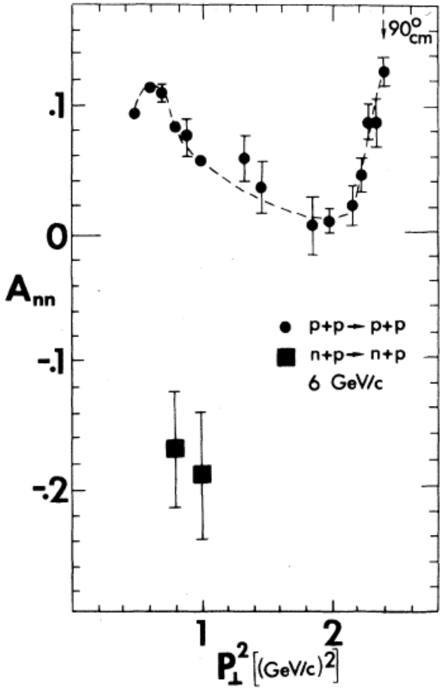
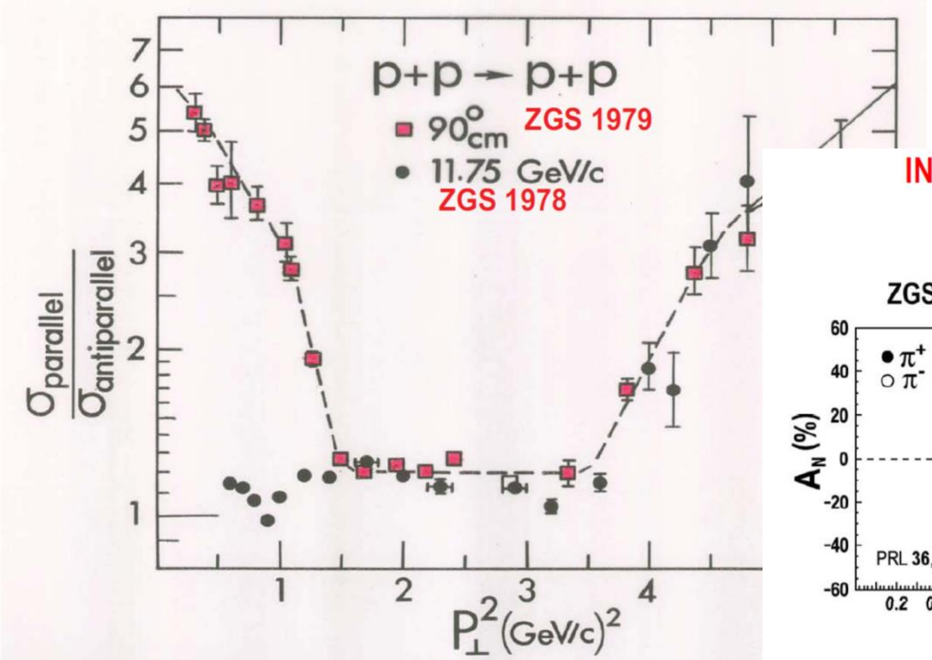
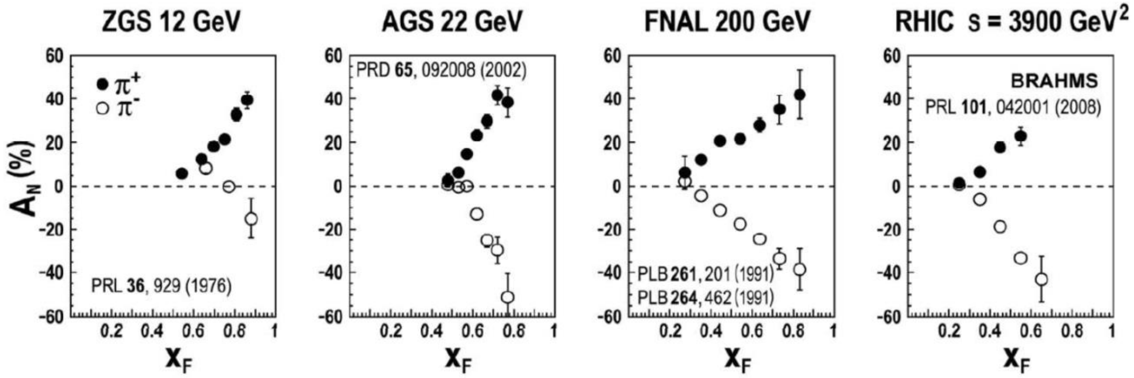


FIG. 2. The spin-spin correlation parameter, A_{nn}, for pure–initial–spin-state nucleon-nucleon elastic scattering at 6 GeV/c is plotted against the square of the transverse momentum. The proton-proton and neutron-proton data are quite different.

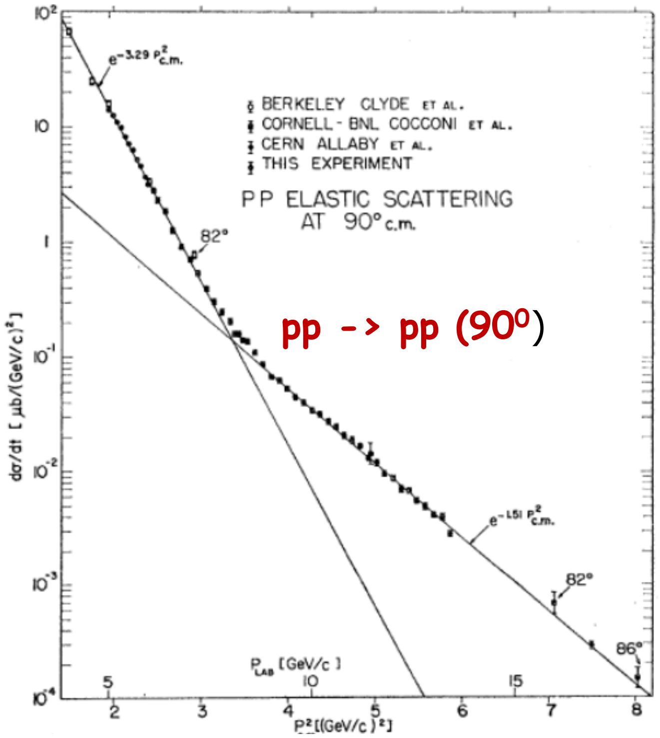


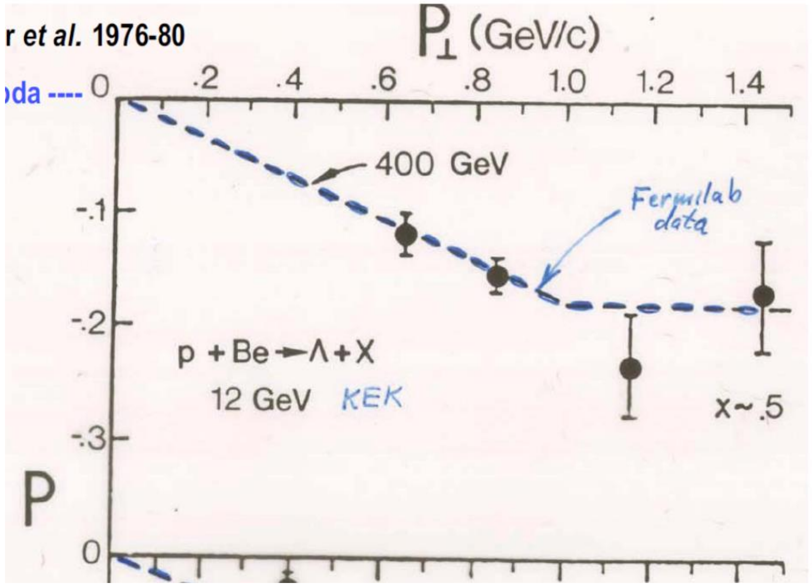
INCLUSIVE PION ASYMMETRY IN PROTON-PROTON COLLISIONS

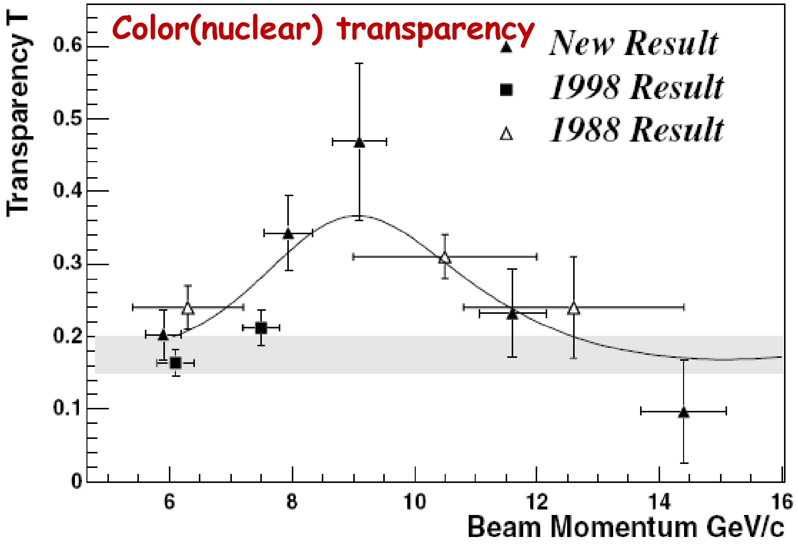
C. Aidala SPIN 2008 Proceeding and CERN Courier June 2009

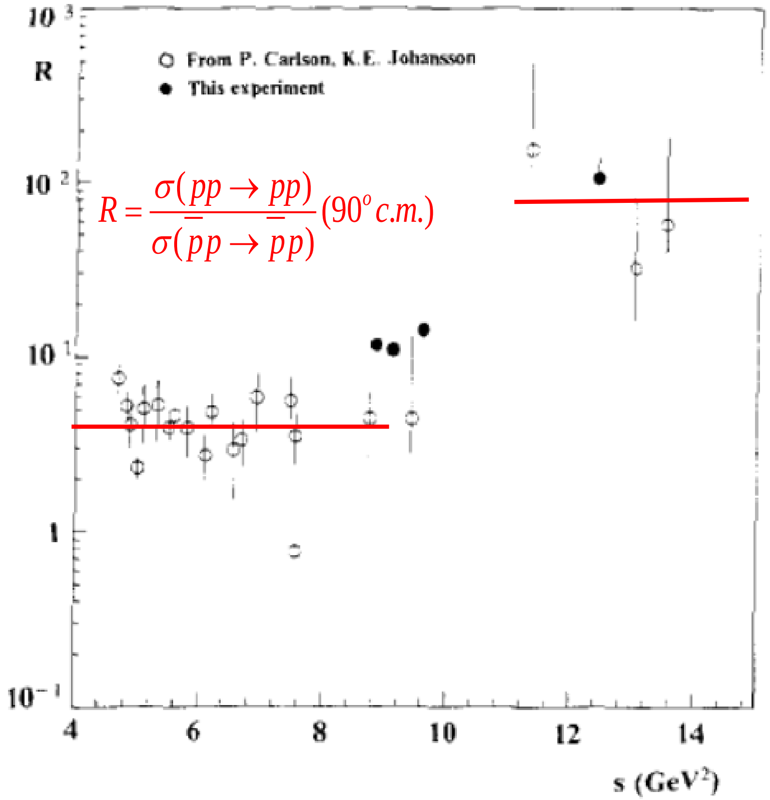


Nonpolarized beams









Exclusive NN study at $x_T \sim 1$

$$N\uparrow + N\uparrow \rightarrow BB + MM$$

B (p,n,Λ, Δ...), M (π, K , ...)

Mechanisms of hyperons polarization

$$N\uparrow N\uparrow \rightarrow NN$$

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

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

$$N\uparrow N\uparrow \rightarrow \Delta\Delta$$

Detail vertexes studies and spin structure of the interaction vertex:

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

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

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

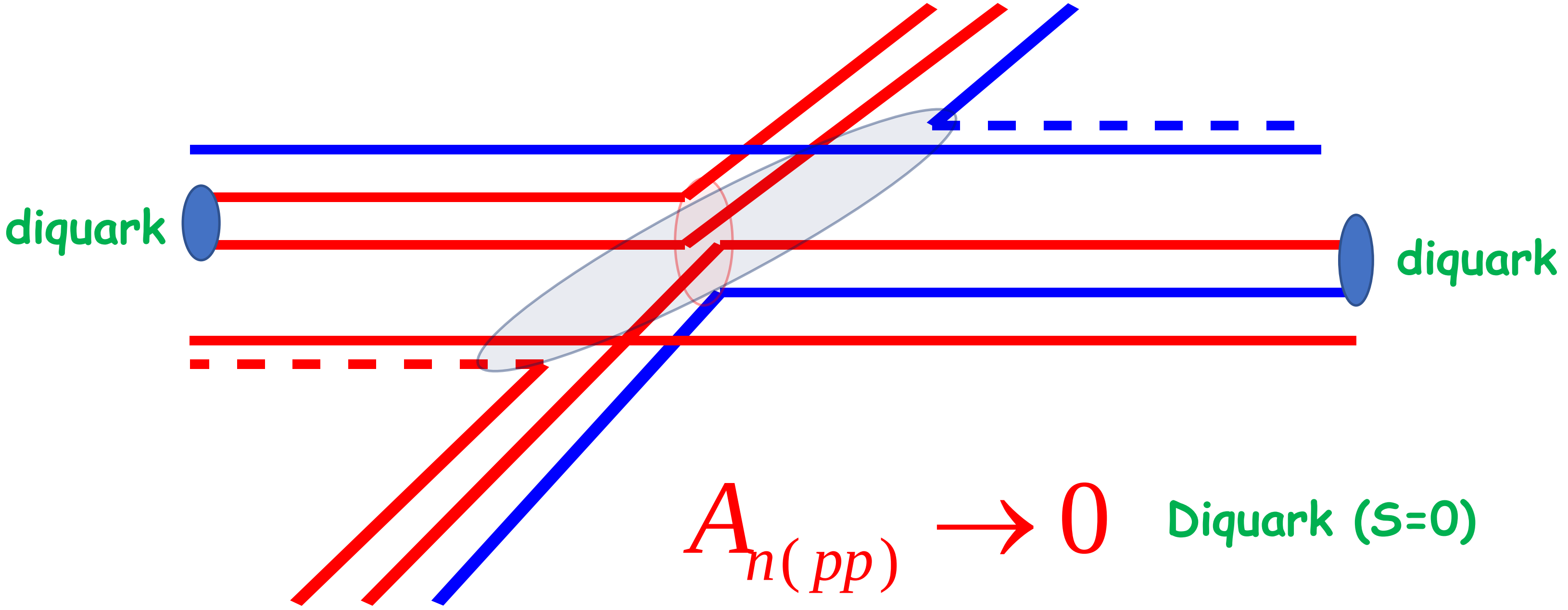
High p_T exclusive reactions -> MPI

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

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

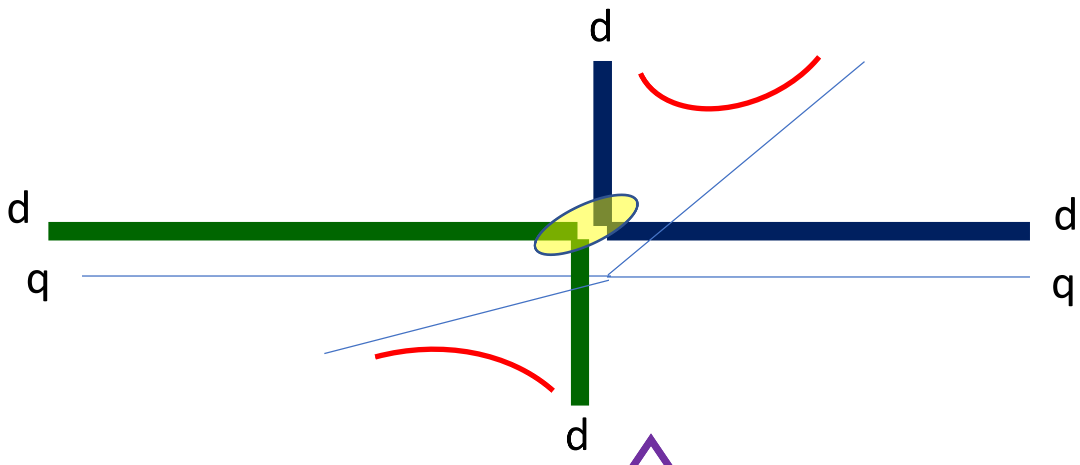
$$R = \frac{N(\pi^+\pi^-)}{N(\pi^0\pi^0)} = \frac{2}{7}$$ Without diquark

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

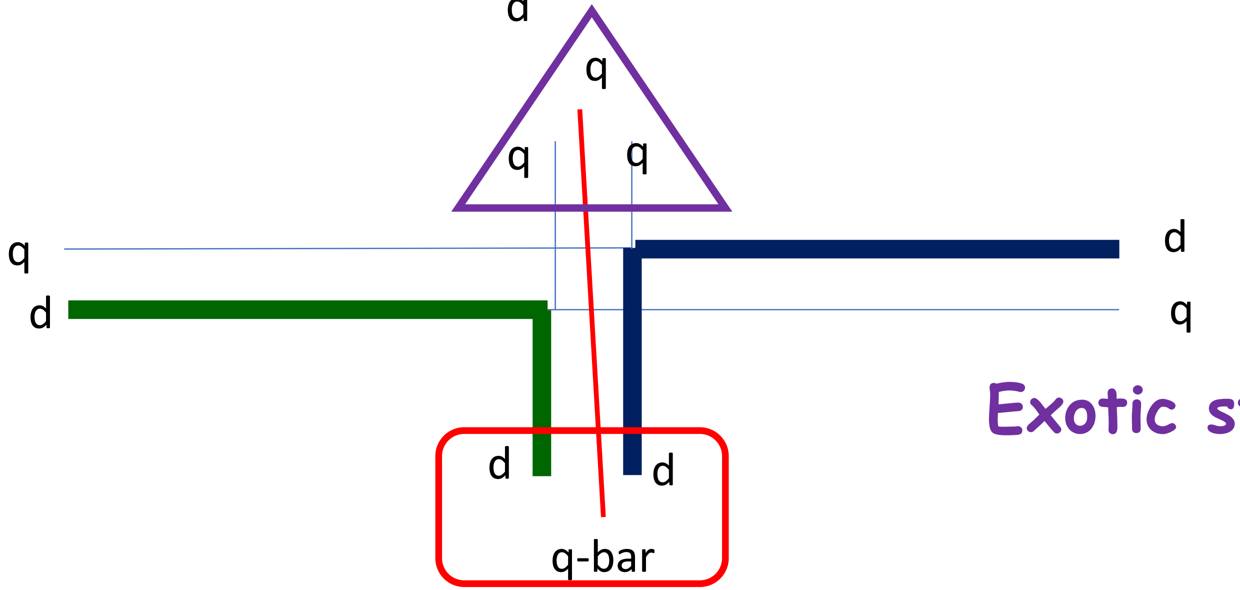


$$A_{n(pp)} \rightarrow 0$$ Diquark (S=0)

pp - reactions with pentaquarks production and …

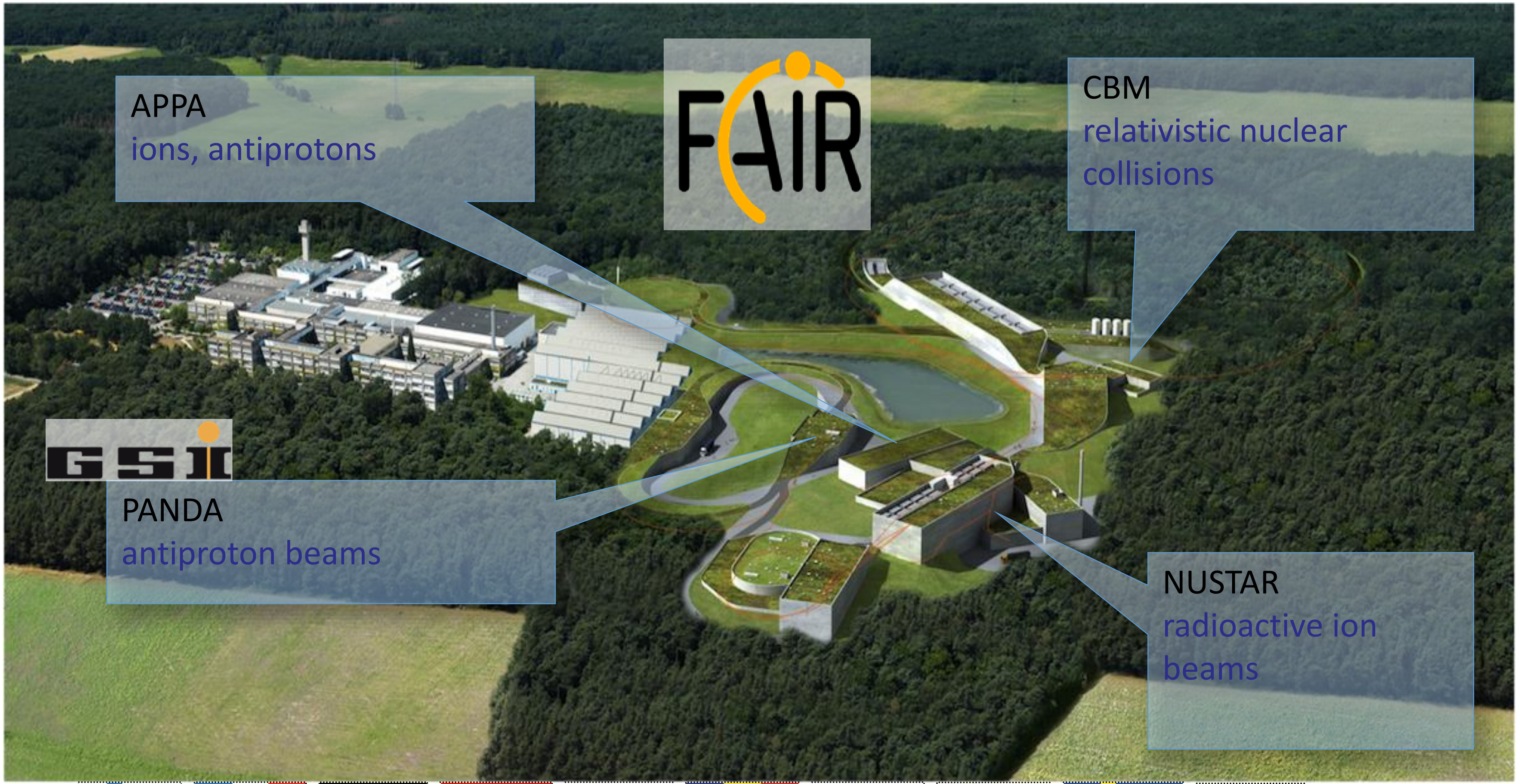


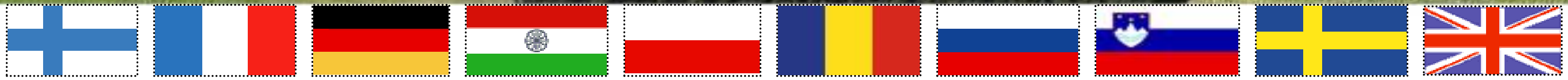
ΛN - interaction



Exotic states production

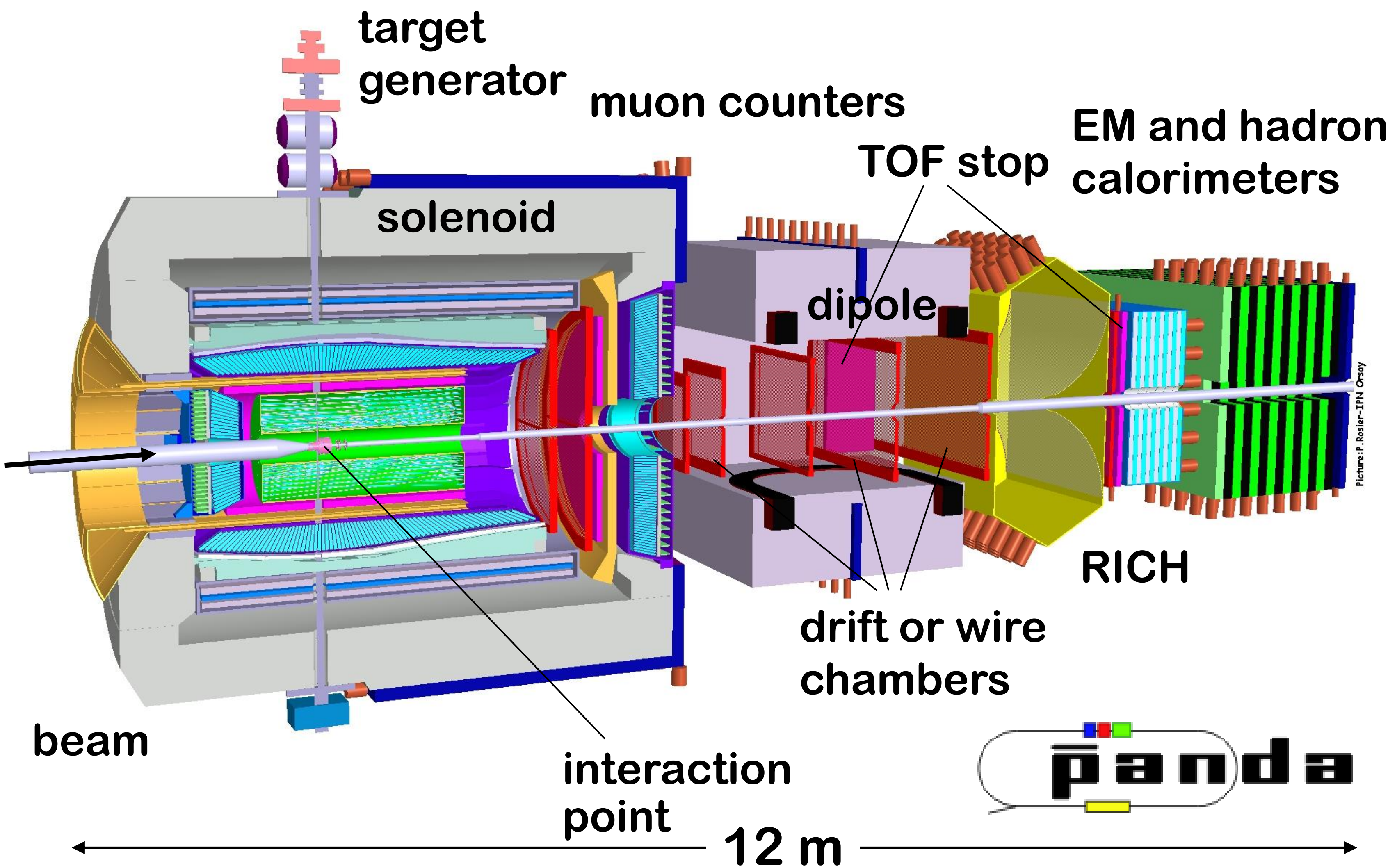
The FAIR Project





Finland France Germany India Poland Romania Russia Slovenia Sweden UK

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



$\bar{p}p$ 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(?)

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

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

$$\bar{p}p \to \bar{\Delta}\Delta$$

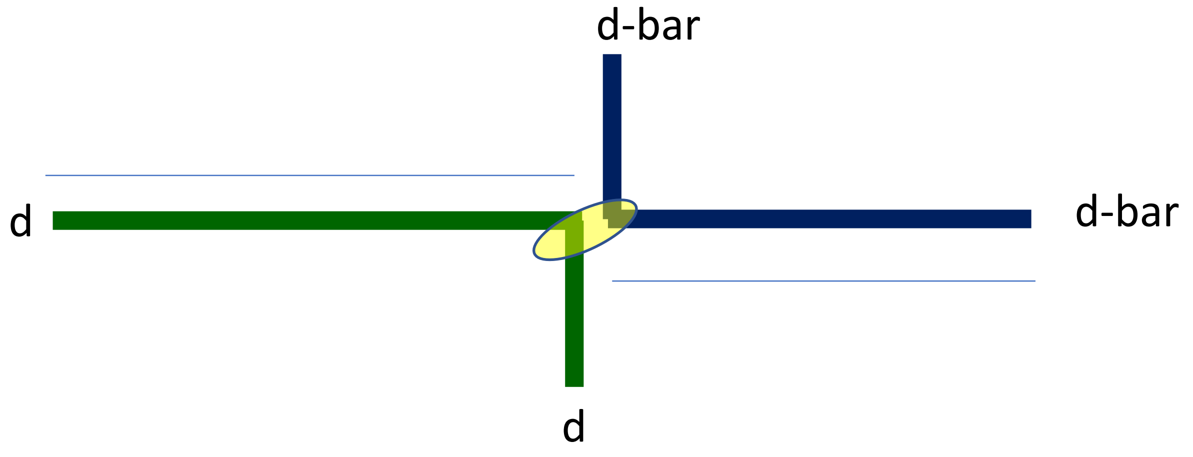
Detail vertexes studies:

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

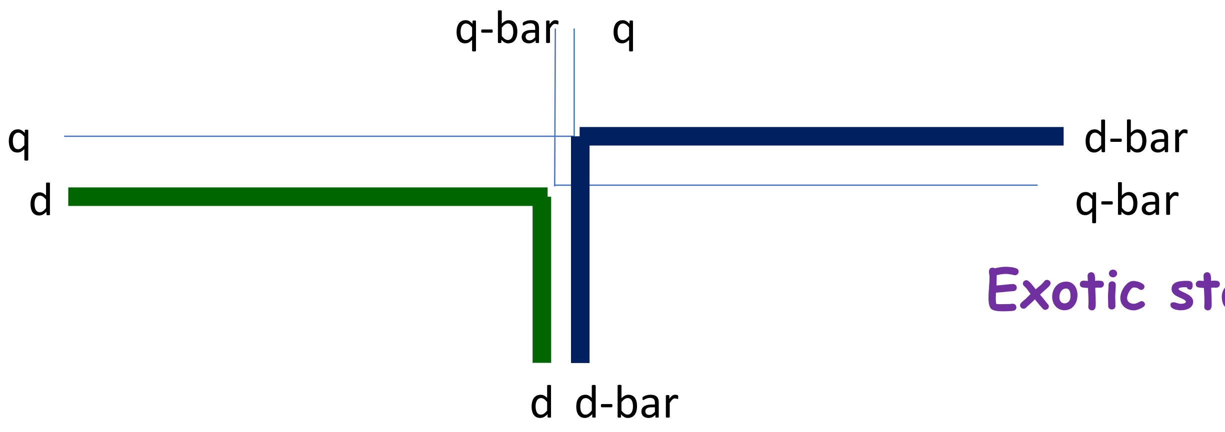
$q(\bar{q}) + \overline{qq}(qq) - (quark - antidiquark)$

$qq + \overline{qq} - (diquark - antidiquark)$

$\bar{p}p$ - reactions with tetraquarks production



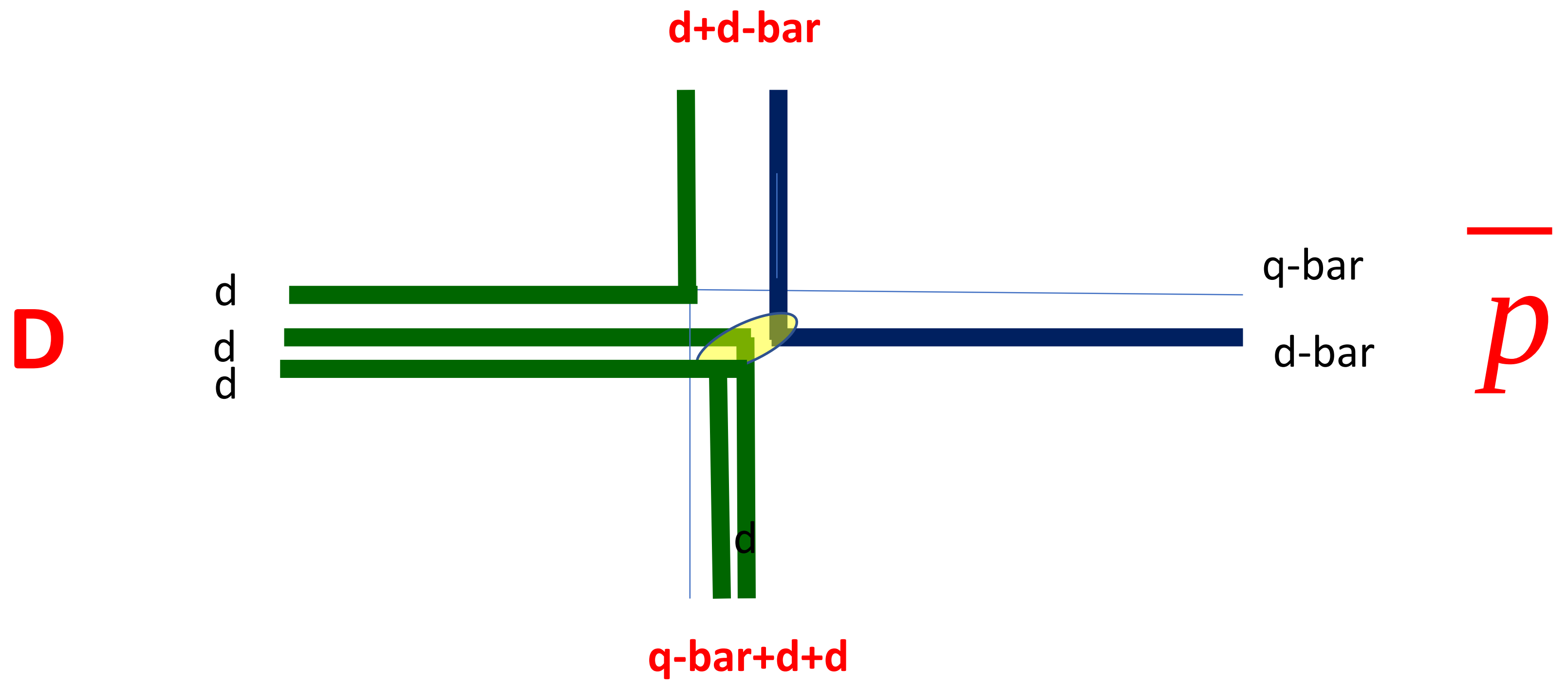
Diquark proof



Exotic states production

Kim's-bar mechanisms

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

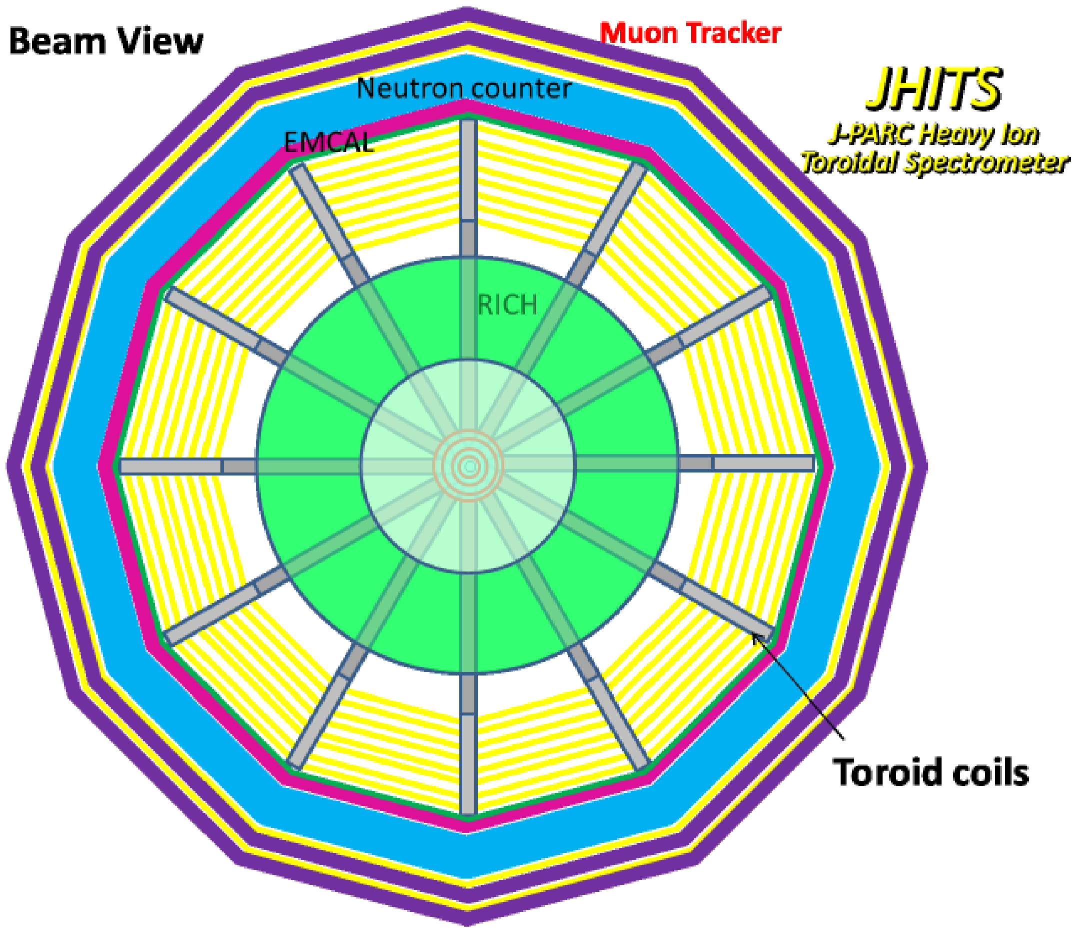


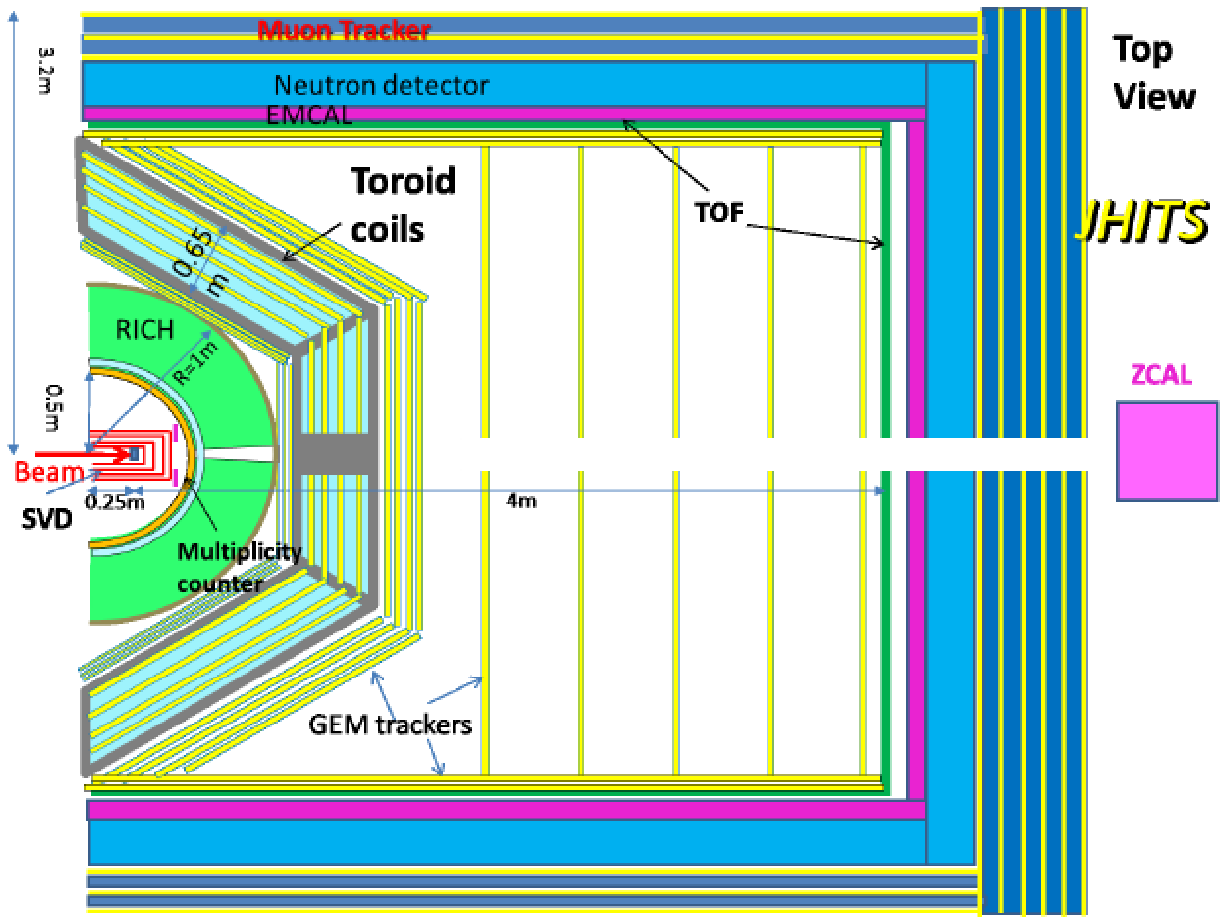
Letter of Intent for J-PARC Heavy-Ion Program (J-PARC-HI)

J-PARC-HI Collaboration

Spokesperson H. Sako*[1,2],

July 25, 2016


Beam View
Muon Tracker
Neutron counter
EMCAL
RICH
JHITS
J-PARC Heavy Ion Toroidal Spectrometer
Toroid coils


Muon Tracker
3.2m
Neutron detector
EMCAL
Top View
Toroid coils
0.65 m
TOF
JHITS
RICH
R=1m
0.5m
ZCAL
Beam
0.25m
4m
SVD
Multiplicity counter
GEM trackers

ALICE

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

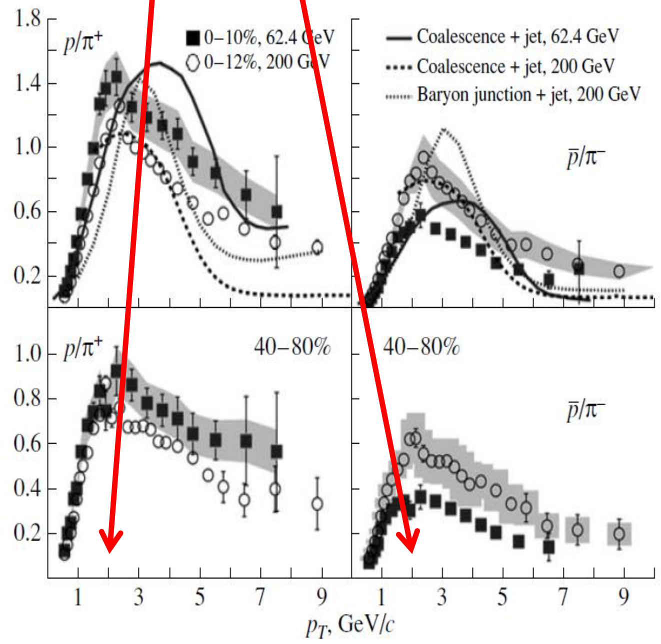


Fig. 3. [10] Ratio of the cross sections for the production of protons and charged pions as a function of the transverse momentum for various degrees of centrality and two beam energies of 62.4 and 200 GeV: (points) results of the STAR experiment and (curves) results of model calculations.

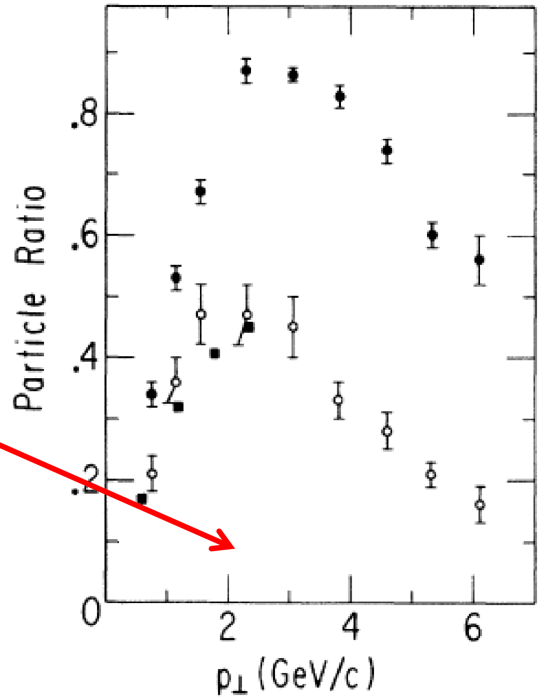
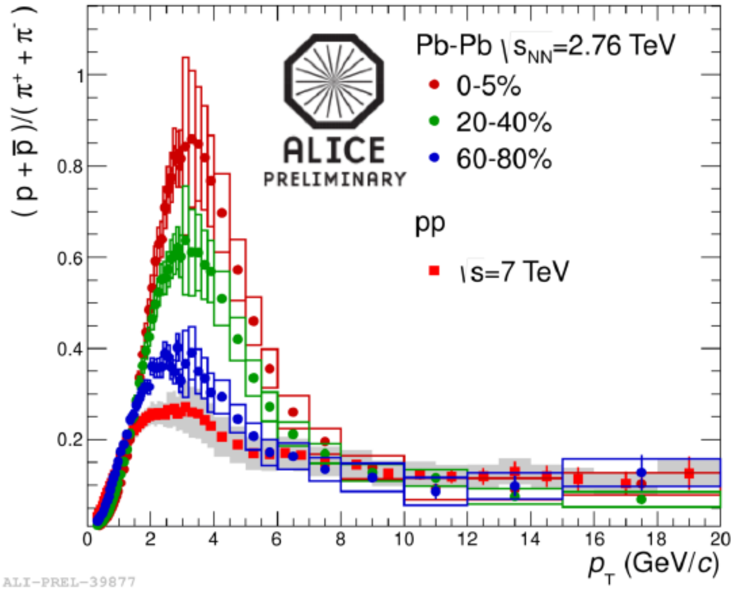
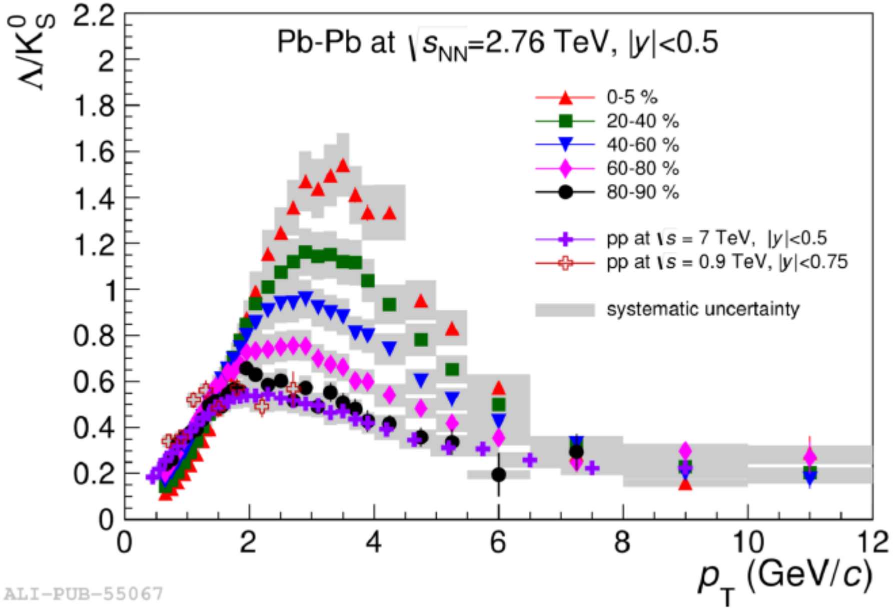


FIG. 20. Comparison of the cross-section ratio p/π^+ measured on tungsten at $\sqrt{s}=23.7$ GeV (closed circles), with that obtained by extrapolation to $A=1$ (open circles). Ratios obtained from the British-Scandinavian collaboration (Ref. 23) at $\sqrt{s}=23.4$ GeV are also plotted (closed squares).

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

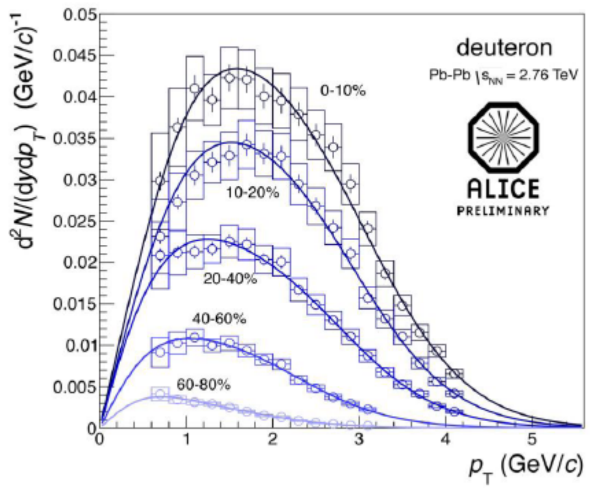
Baryon anomaly in Pb-Pb

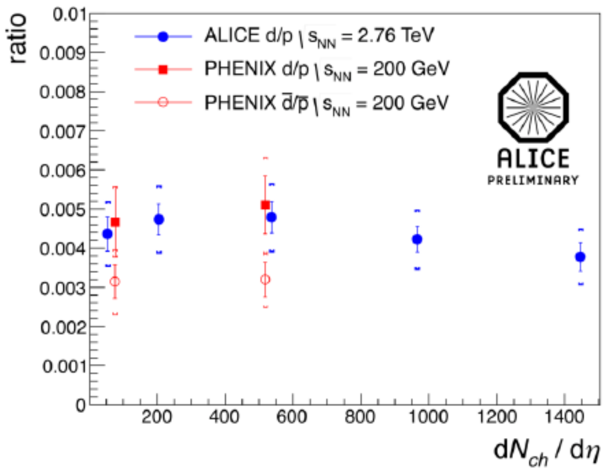




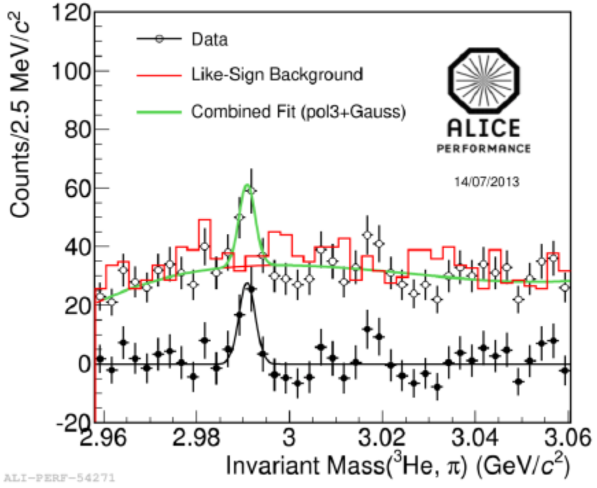
- Baryon to meson ratio increasing with centrality for p_T < 8 GeV/c.
  - Enhancement at moderate p_T is consistent with radial flow
  - May be explained by quark recombination from QGP (coalescence model)
- For p_T > 8 GeV/c no dependence on centrality and collision system
  - Consistent with fragmentation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

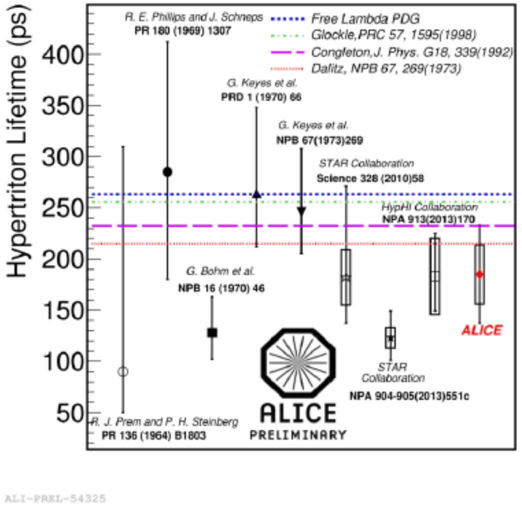
Nuclei and hyper-nuclei





- Deuterons show hardening with increase of centrality (radial flow).
- d/p ratio does not depend on multiplcity.





- Hypertriton (p,n,Λ) yield is measured in Pb-Pb collisions.
- Production rate of $^{3}_{\Lambda}H$ is described by thermal model.
- Lifetime measured.

High p_T Measurements at the CERN SPS

C. Blume

arXiv:nucl-ex/0609022v1 15 Sep 2006

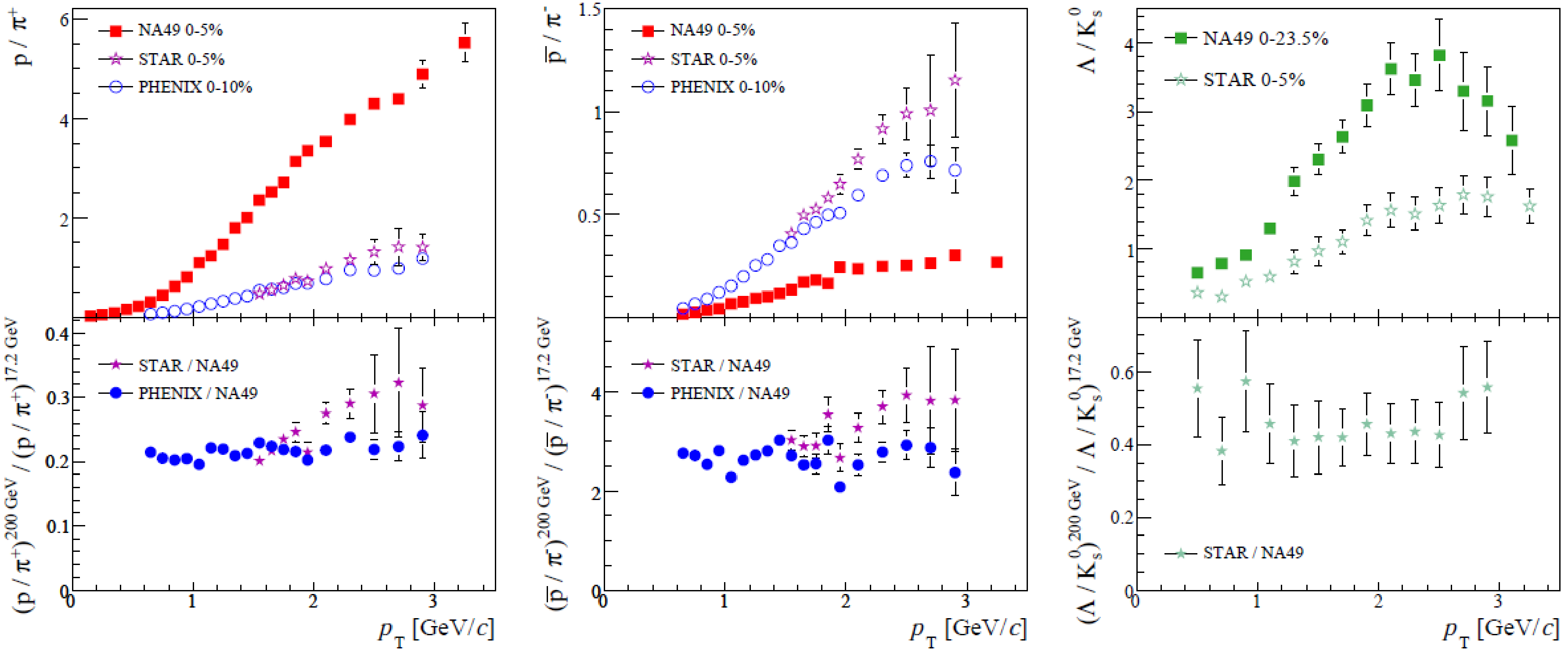


Fig. 6. The baryon/meson ratios as measured by NA49 at $\sqrt{s_{NN}} = 17.3$ GeV [32], compared to results from RHIC at $\sqrt{s_{NN}} = 200$ GeV [33,34]. Please note the different scales of the plots.

ПРИЕХАЛИ!