Production of cumulative particles and light nuclear fragments with high p_T outside the target fragmentation region in pA interactions with 50 GeV protons.

N. N. Antonov[1)], V.A.Viktorov[1)], V. A. Gapienko[1)*],
G. S. Gapienko[1)], V. N. Gres [1)], M. A. Iilyushin [1)], V. A. Korotkov [1)],
A. I.Mysnik [1)], A.F.Prudkoglyad [1)],Pryanikov D.S.[1)] A. A. Semak [1)],
V. I. Terekhov [1)], V.Ya.Uglekov [1)],
M. N. Ukhanov [1)], B. V. Chujko[1)], and S. S. Shimanskii [2)]

[1)] Institute for High Energy Physics, Protvino, Moscow reg., 142284 Russia.
[2)] Joint Institute for Nuclear Research, Dubna, Moscow reg., 141980 Russia.

Email:Artem.Semak@ihep.ru

Plan:

1 Advantages of the SPIN experiment

2 Experimental setup layout, spectrometer parameters and particle identification

3 Physical results

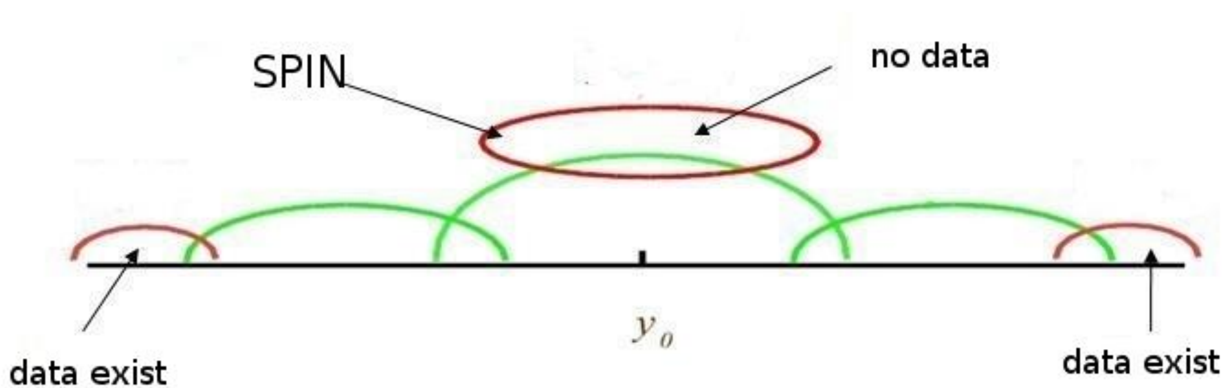
4 Conclusion

Advantages of the SPIN experiment

Investigations of the kinematical region forbidden for processes involving free nucleons have been performed for many decades, and a large volume of experimental data has been obtained in these investigations(see, for example, G. A. Leksin, Phys. At. Nucl. **65, 1985 (2002).**). Processes leading to the production of particles in the kinematically forbidden region were called cumulative processes.

The region of high transverse momentum (p_T >2 GeV/c), where cumulative processes have not yet been studied experimentally, are especially interesting. Theoretical analysis performed in [A.V.Efremov, V.T.Kim and G.I.Lukasov,Sov.J.Part.Nucl.,44(1986)151] indicated that at $x_T \sim 1$ multiquark (multinucleon) configurations are dominated in comparison with multiscattering processes.

SPIN provide study far from target fragmentation region.



Unusual features of cumulative processes

***1** weak dependence of observed spectra of the type of incident particles indicate the existence of a source cumulative particles in the nuclear matter*

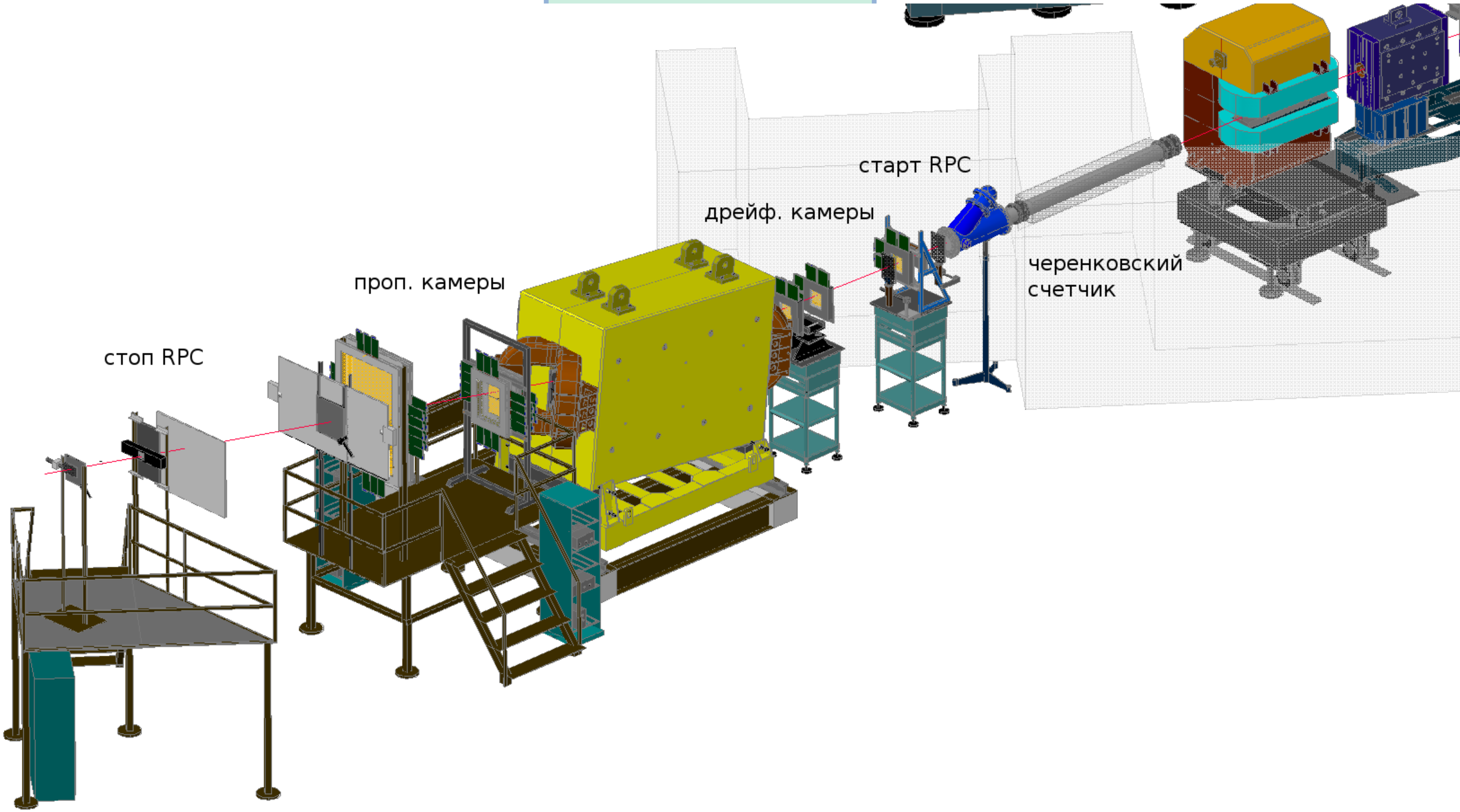
***2** source of cumulative particles isotopically symmetric: there is equality cross sections of the yield of particles with opposite isospin* ($\pi^+/\pi^- \approx 1$ $p/n \approx 1$ $t/{}^3He \approx 1$)*;*

***3** close yields* K^+/π^+ (X) ≈ 1 *and increased yield of nucleons*

***4** there is a strong A - dependence when increasing the cumulative number the exponent of A may exceed unit*

Second and fourth properties will seen in our data set

SPIN setup



protons

10^{12} - 10^{13} /cycle

Experimental setup parameters:

- System of 6 magnets gives a possibility to accept charge particles emitted from target with polar angles $22^0 - 55^0$ lab. syst. Presented data were taken for the angle of 35^0
- System of wire chambers installed before and after sixth magnet provides with the momentum measurement accuracy of $\sigma(p)/p \approx 3\times10^{-3}$
- Angular acceptance: azimuth $\Delta\varphi \approx 100$ mrad, polar angle $\Delta\theta \approx 40$ mrad
- momentum acceptance changes from 5.5% at 1 GeVc to 3.5% at 6 ГэВ/c.
- Secondary emission chamber measured the proton beam intensity in range of 10^{12} - 10^{13} protons/s.
- Table of used targets:

target	C	Al	Cu	W
thickness (g/см^2)	0.86	0.81	0.90	0.64

- **System of particle identification consist of: thresold cherenkov gas counter and Time Of Flight system.**

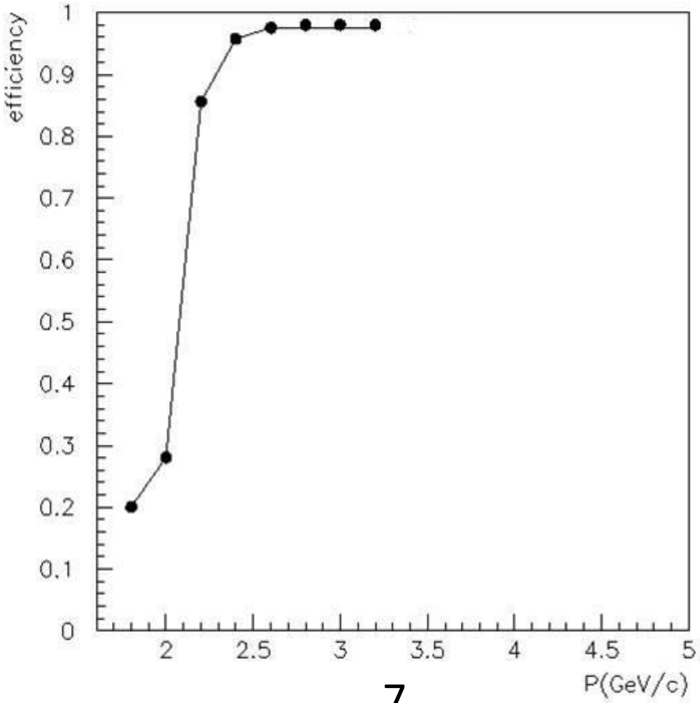
Cherenkov counter

separates pion in interval of 2.5 -7 ГэВ/c

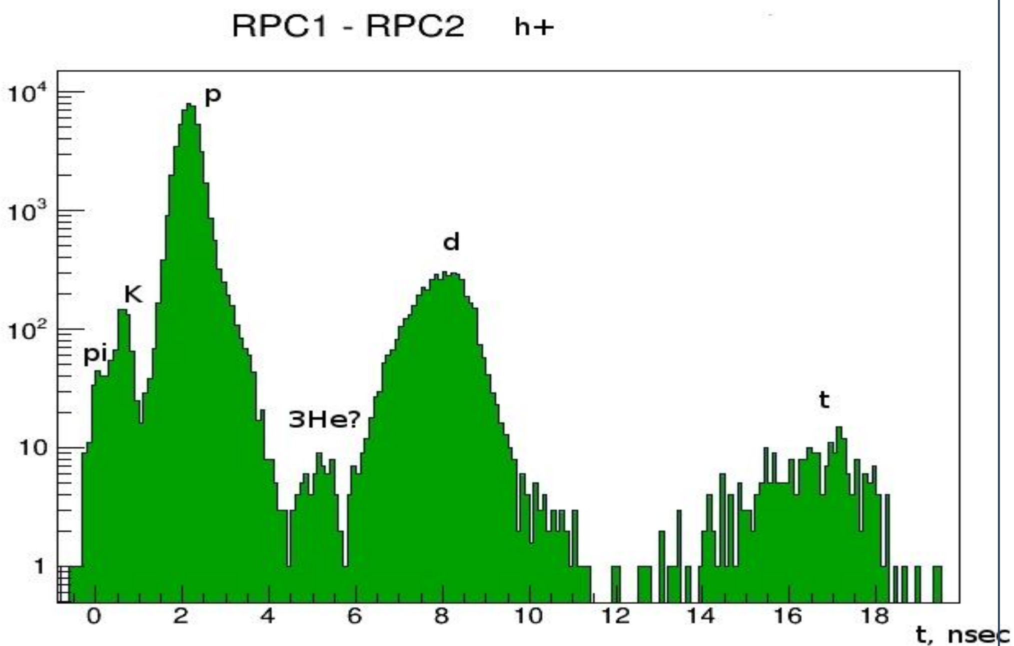
Gas: freon 318 at 1.7 атм
radiator length: 3 m

PMT XP2041/Q (quartz window, d=110 mm)

efficiency ~99%, wrong counts due to high backgraund rate- 1%



Data 2013. Time Of Flight system

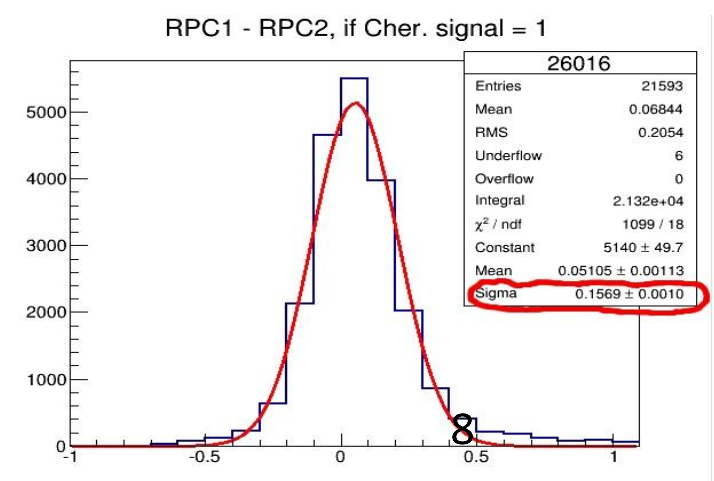


Two 12-gap RPC strip readout.
Strip width – 25 mm
Active area of start RPC 20x22 cm ^{2}
Active area of stop RPC 33x68 cm^2

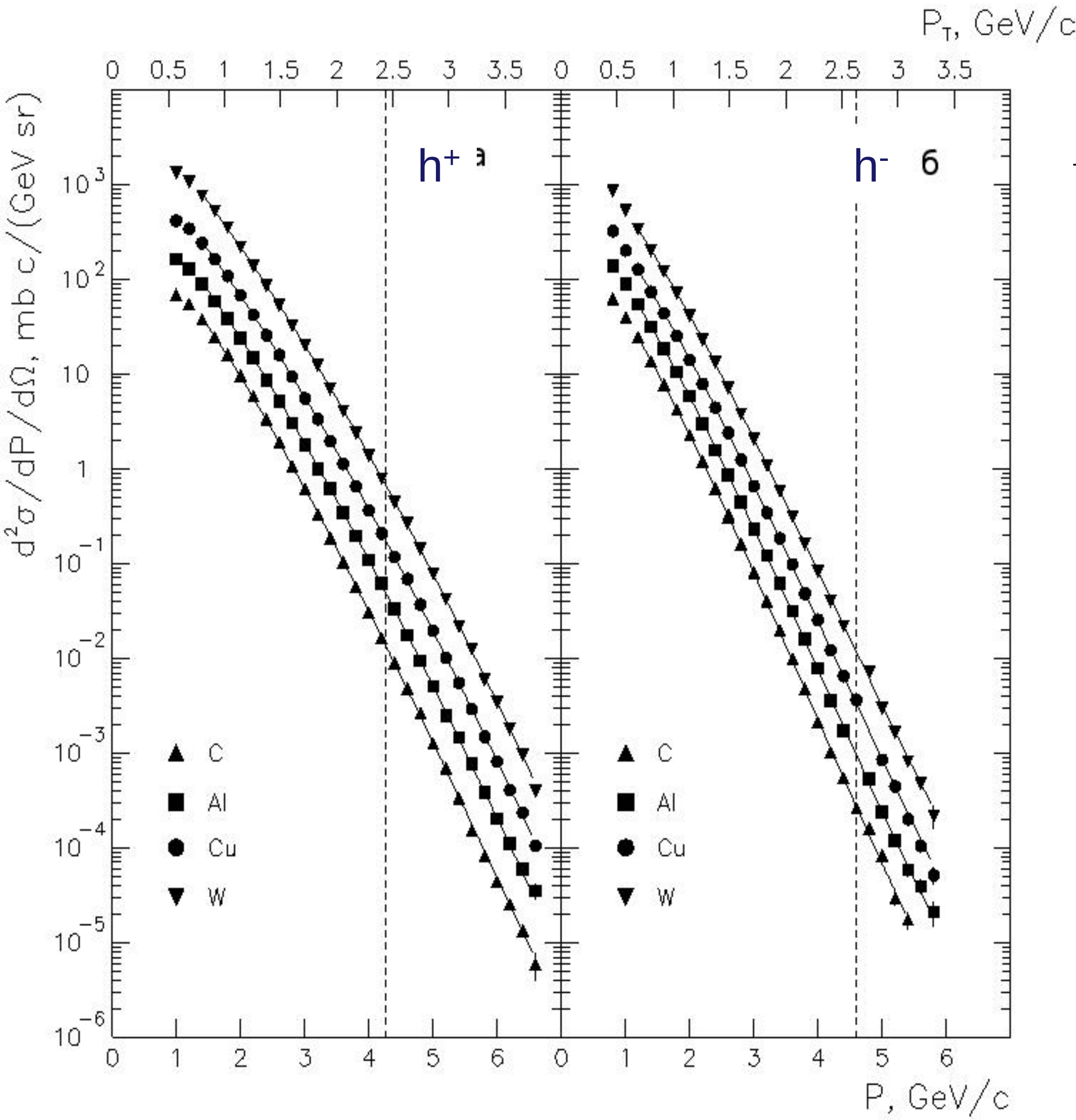
Both RPCs were made of commercially available glass. To increase a rate capability of the start RPC which operated in flux of 2-3 kHz/cm^2 it was warmed up to 40 ±0.5 °C.

As for FEE the ALICE TOF amplifier-discriminator was used

The resolution of the TOF system estimated from the pion signal width was found to be 160 ps



The first data with particles beyond of the NN kinematical limit (2009-2010)



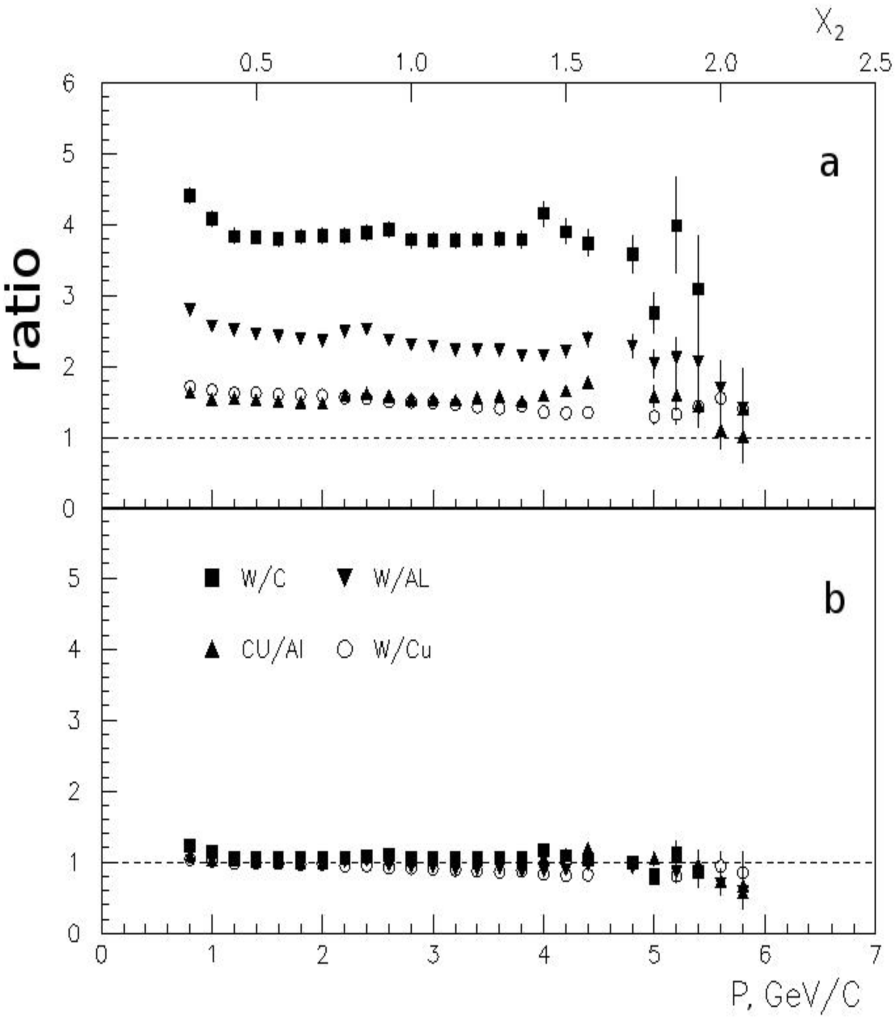
$$\frac{d^2\sigma}{dP\cdot d\Omega} = \frac{A}{N_A\cdot\rho\cdot t}\cdot\frac{1}{\varepsilon\cdot\Delta P\cdot\Delta\Omega}\cdot\frac{N^h}{N_{prot}}$$

The production of cumulative particles with high transverse momentum has been observed for both sign in interactions of 50 GeV protons with four different nuclear targets.

Lab.sys. angle = 35^0

The data analysis within of Stavincky variables X1 and X2 (2009-2010)

p+A→π⁻ +X



If to parameterize the cross-section with [Baldin A.A., JINR № 3-92, 1992,p.27-37, № 4-96, 1996, p. 61-68; JINR№ 2-99, 1999, p.. 20-29]

$$f = E\frac{d^3\sigma}{dp^3} = C_1 \cdot A_1^{\frac{1}{3}+\frac{X_1}{3}} \cdot A_2^{\frac{1}{3}+\frac{X_2}{3}} \cdot e^{-\frac{\Pi}{C_2}}$$

where C_1 и C_2 - constants, A_1 и A_2 – atomic mass

and $\Pi = \frac{\sqrt{s_{\min}}}{2m_N}$, one can find $\frac{f_{(p+A_I)}}{f_{(p+A_{II})}} \times \left(\frac{A_I}{A_{II}}\right)^{-(\frac{1}{3}+\frac{X_2}{3})} = 1$

As for SPIN data it was found that the ratio of cross-sections multiplied by reverse dependence on A becomes to be unit only

$A^{(\alpha+X_2)/3}$ə on atomic mass is taken as

and **α = 2.45 ± 0.04**

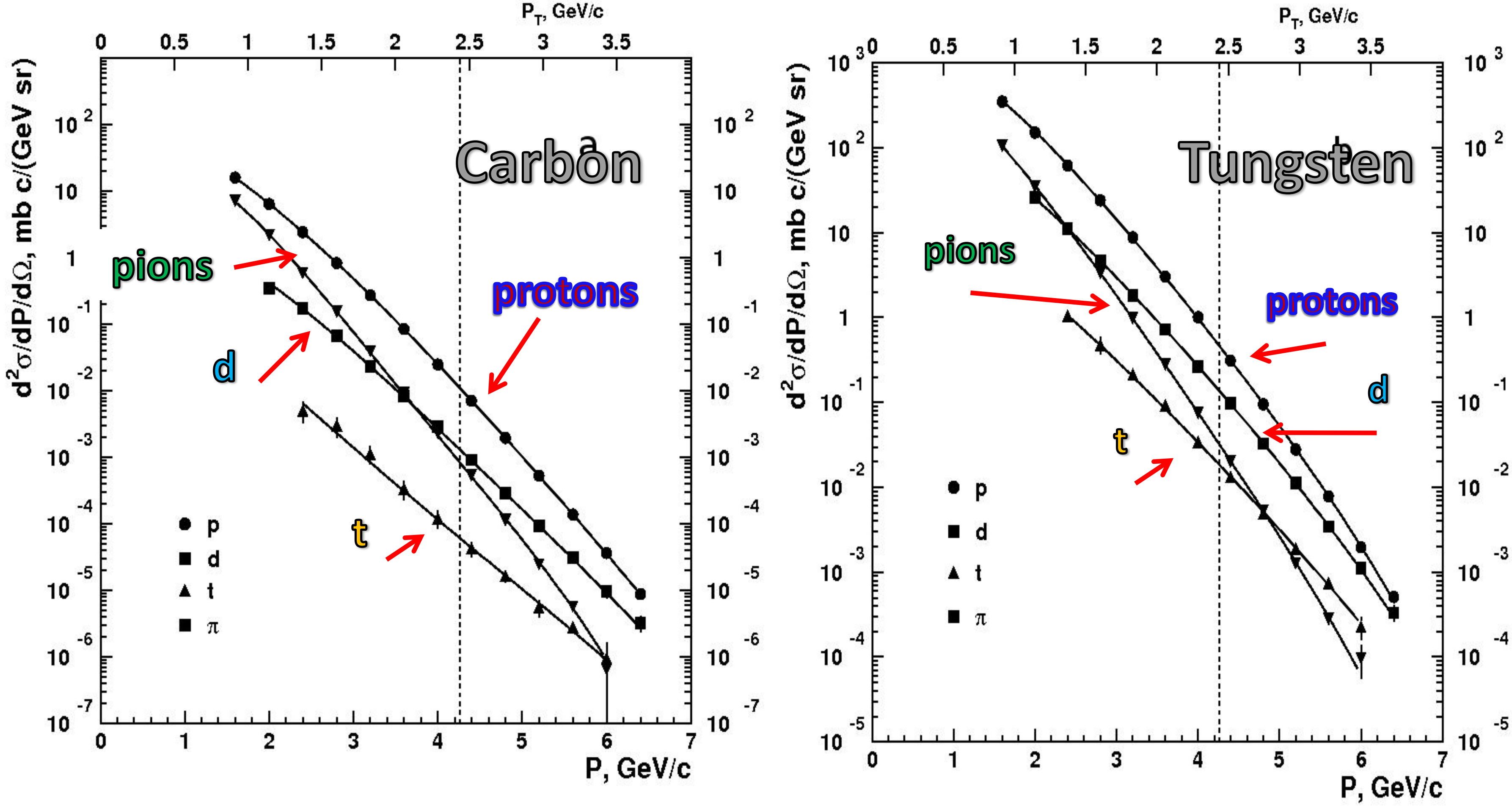
Upper part of figure **α = 1**

Low part: **α = 2.45**

parameterization describes well enough a dynamic dependence on X2

strong dependence on atomic mass was observed: (α + X2)/3 > 1 pointed out on multinuclon reaction

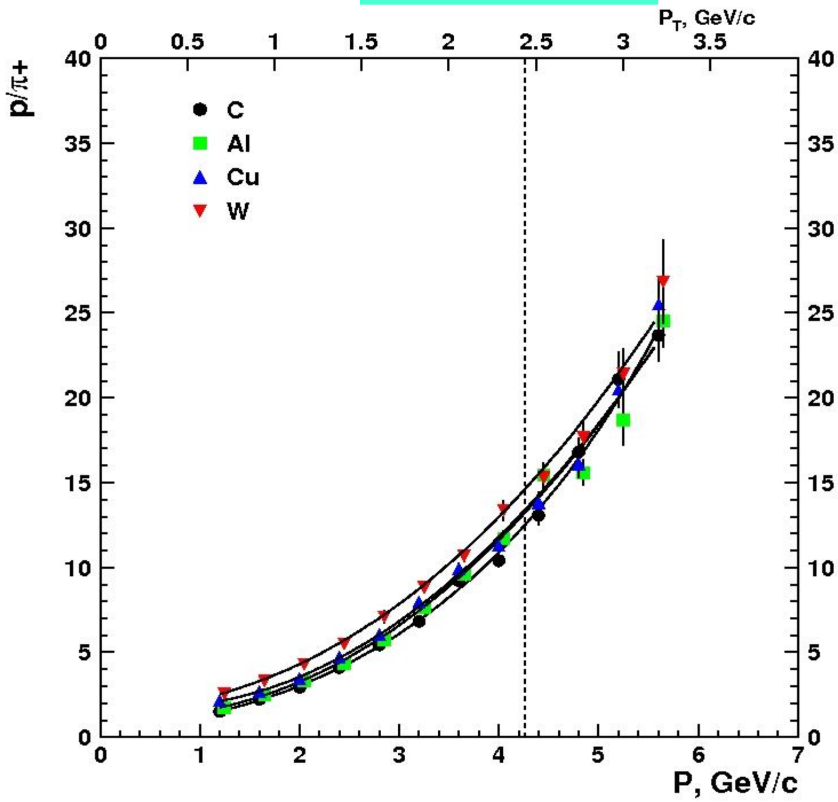
Particle Spectrums (2013)



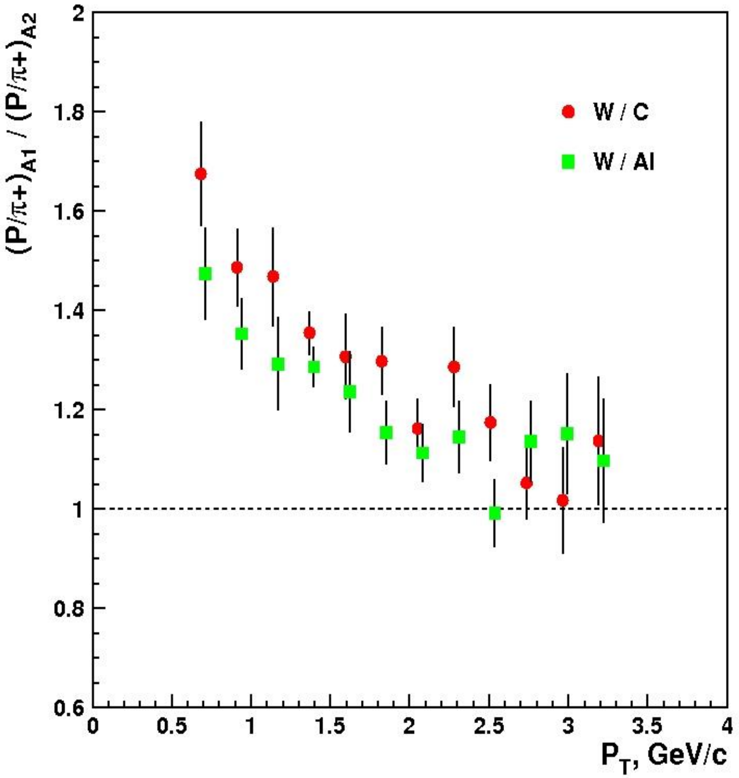
Invariant function found for positive pion, proton, deuteron and triton.
The vertical dashed lines indicate the kinematical limit for elastic nucleon–nucleon scattering. The upper horizontal scale shows values of the transverse momentum p_T .

Proton to positive pion ratio (2013)

p/π+ rations



comparison of p/π+ found for W and for more light nuclei.

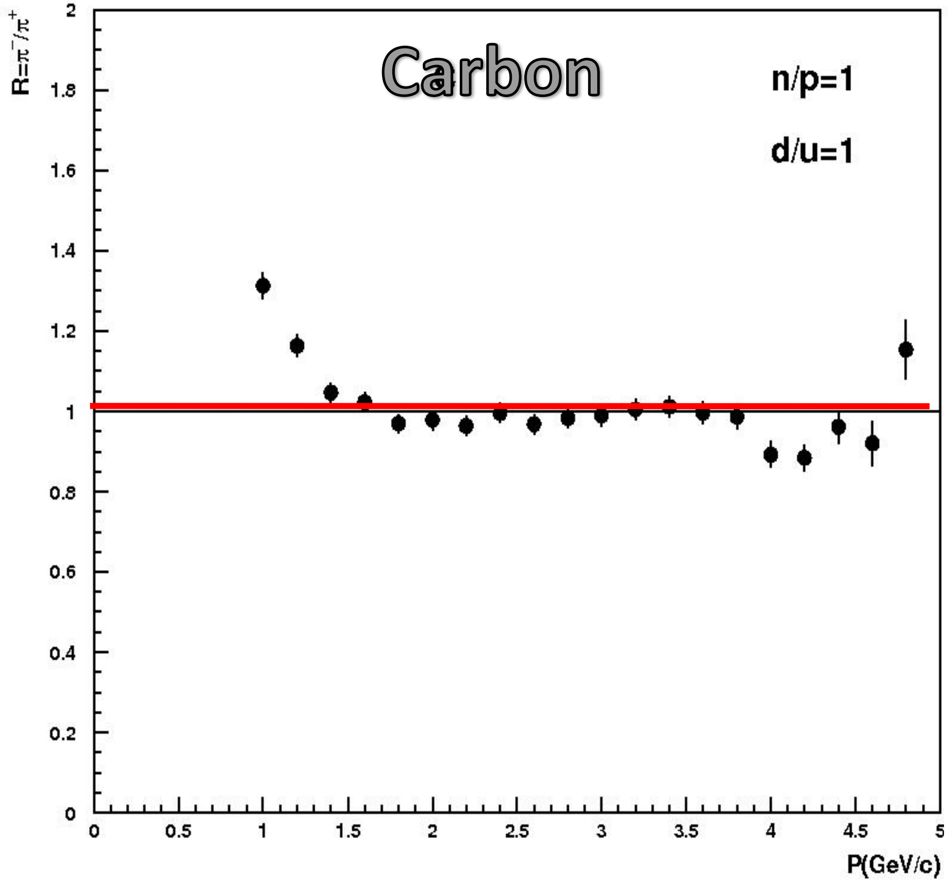


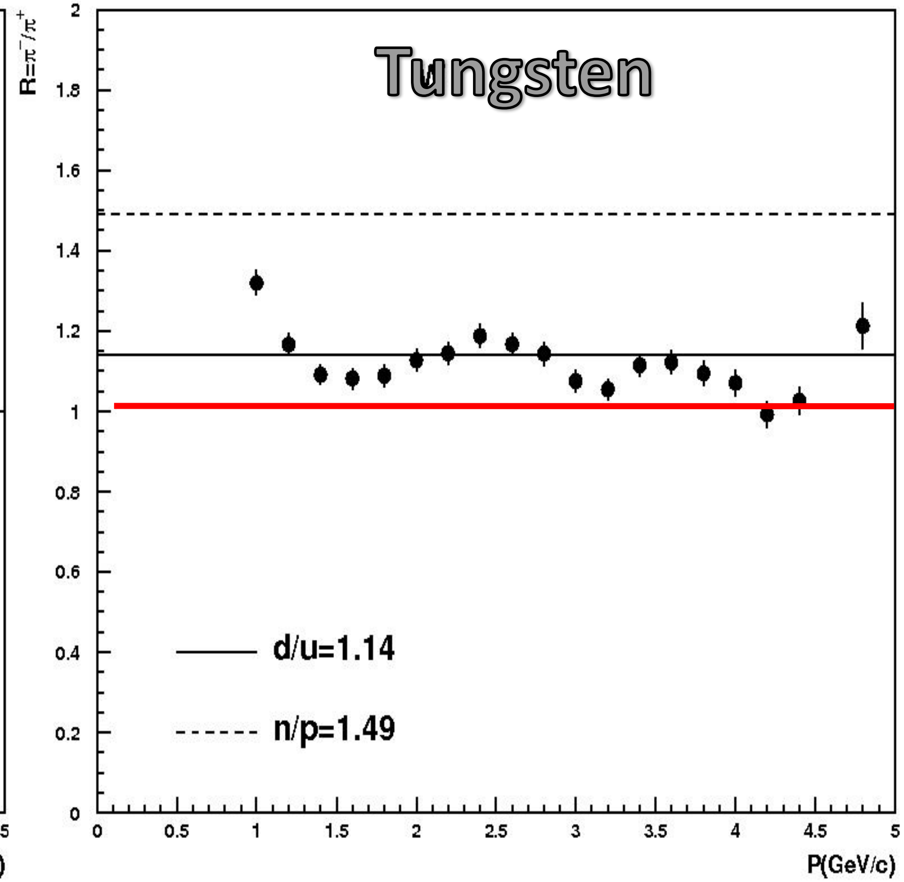
Valence quarks dominate over sea quarks: output of π+ at high p_T becomes to be negligible

Asymptotic tells that a ***mechanism*** of the high p_T particle production ***is local***

Isotopic Symmetry

The π^-/π^+ ratio indicate that
fluctone structure rather corresponds to the quark structure

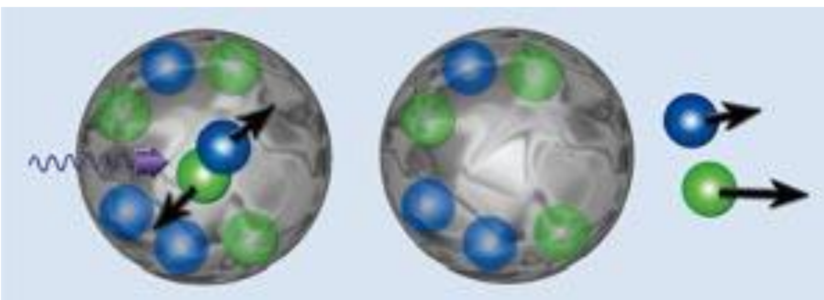


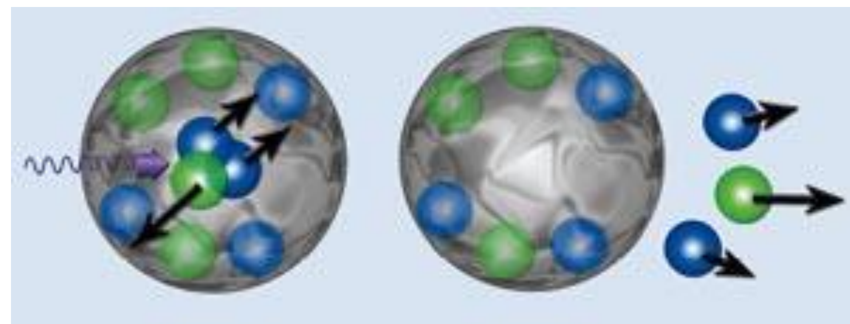


CERN Courier, N9 2005

Close nucleon encounters

Jefferson Lab may have directly observed short-range nucleon correlations, with densities similar to those at the heart of a neutron star. Mark Strikman explains.





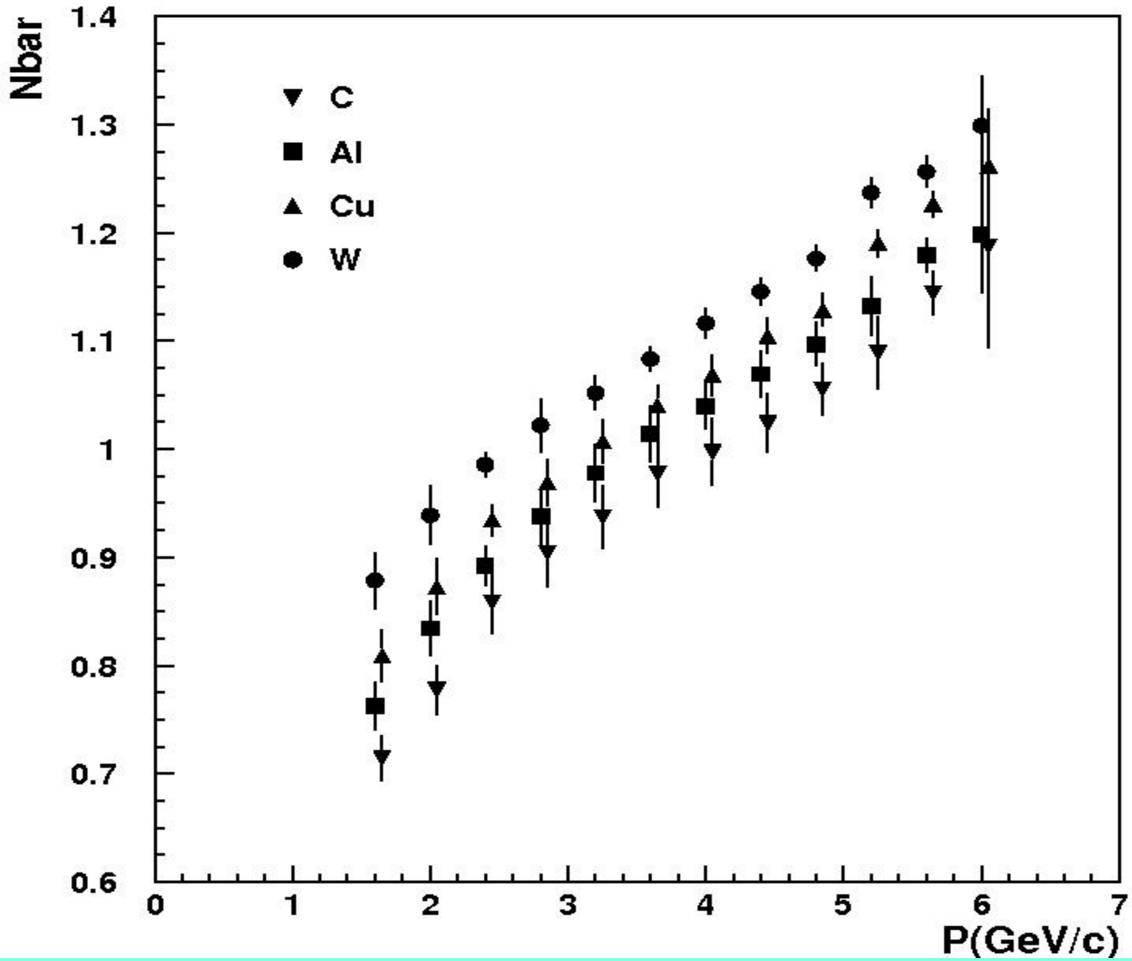
nucl-ex/0508026

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

K.S. Egiyan,[1] N.B. Dashyan,[1] M.M. Sargsian,[10] M.I. Strikman,[28] L.B. Weinstein,[27] G. Adams,[30] P. Ambrozewicz,[10]
M. Anghinolfi,[16] B. Asavapibhop,[22] G. Asryan,[1] H. Avakian,[34] H. Baghdasaryan,[27] N. Baillie,[38] J.P. Ball,[2]

Fluctton or SRC?

Mean baryon number as a function of recoil momentum.



By knocking out "fluctons" may experience increased yield nuclear fragments.

If the SRC mechanism works the average number of registered baryons should remain close to unity. Because correlated nucleons with large relative momentum have a opposite direction of movement.

General Conclusions

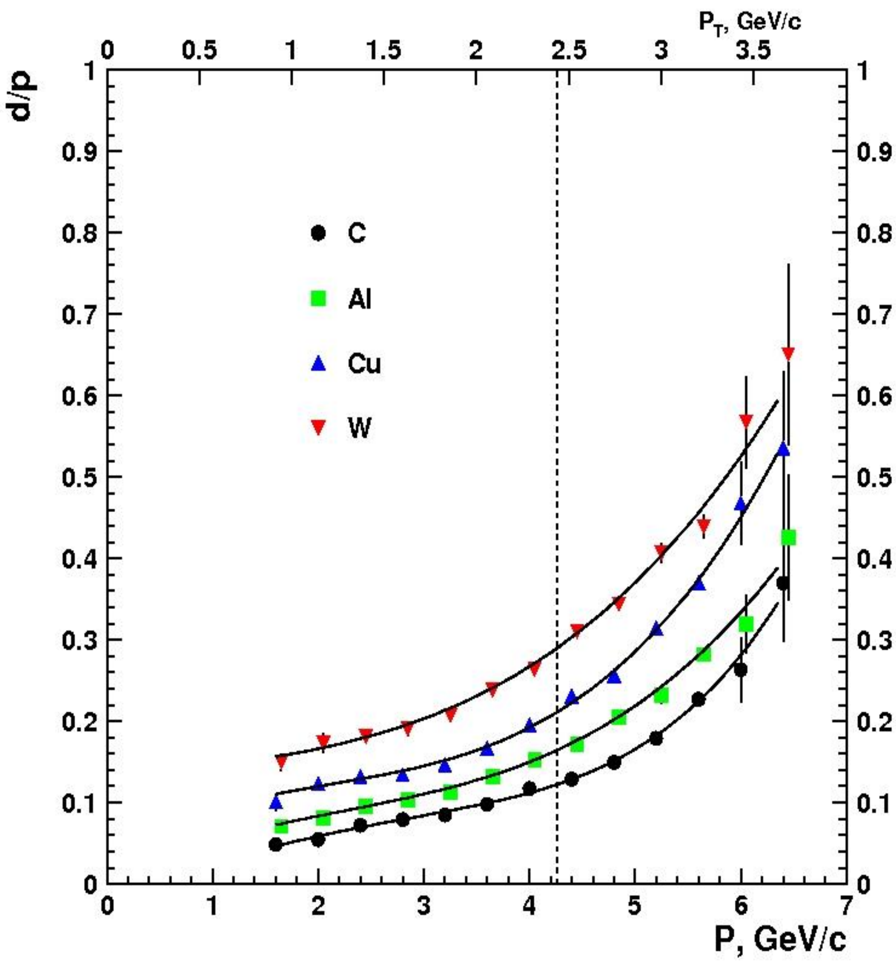
Output of the high transverse momentum protons and light nuclear fragments in cumulative region can be considered as an indication that they were produced in interactions with multinucleon /multiquarks objects (fluctions).

*A rise of the light nuclear fragments (d,t) output relatively to output of proton observed with growth of momentum can be hardly explained with the Short Range Correlations model** *according to which proton (neutron) should dominate among cumulative barions knocked with high momentum out of nuclei.*

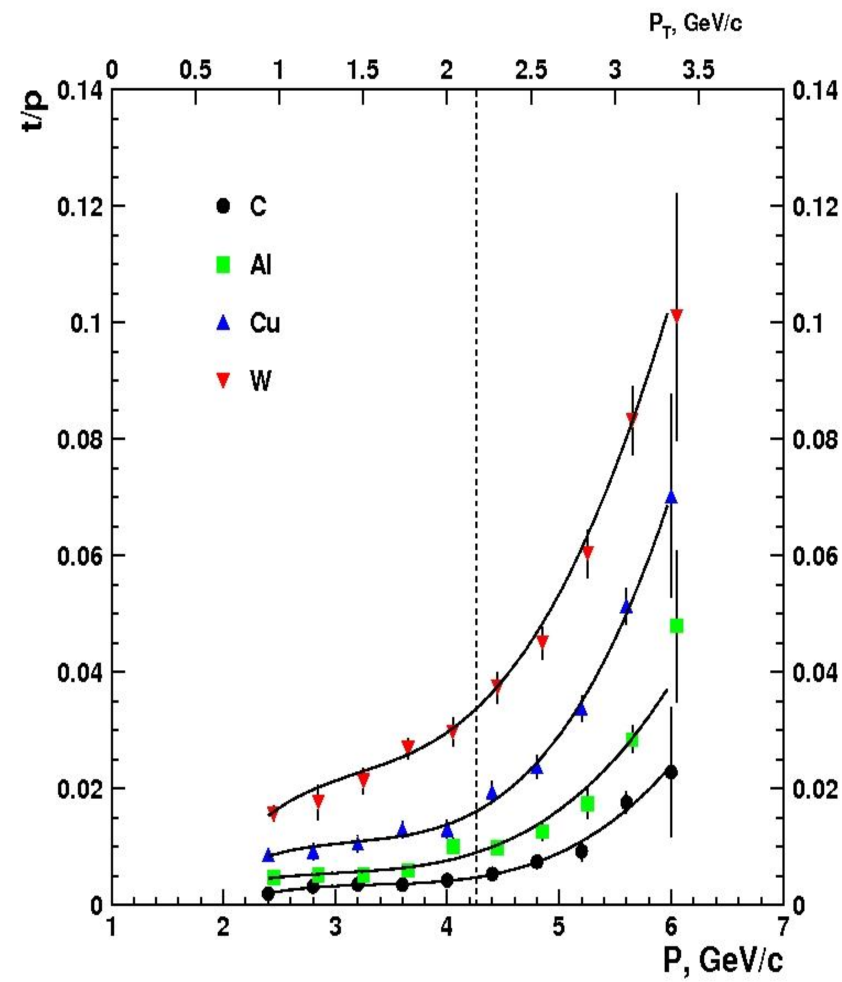
*. М.И. Стрикман, Л.Л. Франкфурт, ЭЧАЯ, т.11,1980,с.571
J. Arrington et al., Progr.Particle and Nuclear Physics 67 (2012) 898–938

d and t production

deuteron to proton ratio



triton to proton ratio



The triton fraction rise faster than the deuteron fraction