PHYSICS PROGRAMME FOR THE FIRST STAGE
OF THE NICA SPD EXPERIMENTS

Yu. N. Uzikov

DLNP JINR

on behalf of the coauthors of the paper arXiv:2102:08477 [hep-th]

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/NICA SPD workshop , 5-6 October, 2020/

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Prepared for Physics of Elementary Particles and Atomic Nuclei. Theory

Possible studies at the first stage of the NICA collider operation with polarized and unpolarized proton and deuteron beams

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SPD at energies $\sqrt{s_{NN}} = 3.4 - 10$ GeV and QCD

TOPICS

- Helicity amplitudes of elastic pN scattering & spin observables in p-d and d-d elastic and quasi-elastic scattering
- Polarized large angle pN elastic scattering
- Color transparency
- Deuteron structure at short distances, SRC in nuclei, dimensional scaling, multiquark configurations
- Single spin asymmetries in p+p(A)->π X, pX and quark models
- Charm production of pN- collisions
- Hypernuclei
- Search for Physics beyond the Standard Model

SPD AT NICA

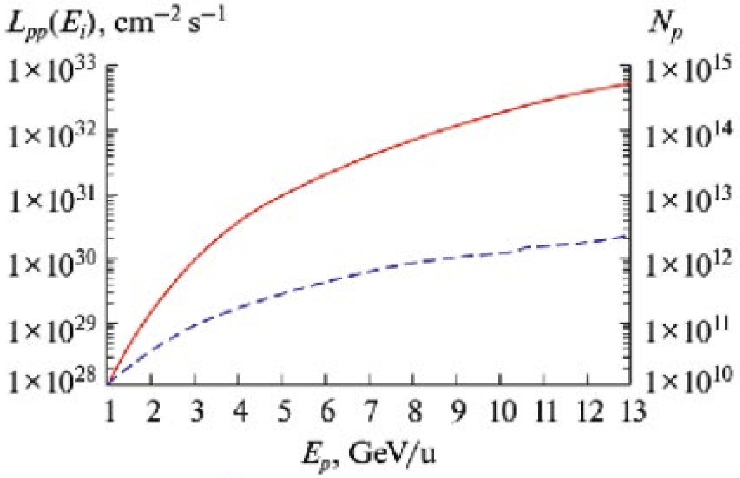
$p^{\uparrow}p^{\uparrow} : \sqrt{s} \leq 27\ GeV$

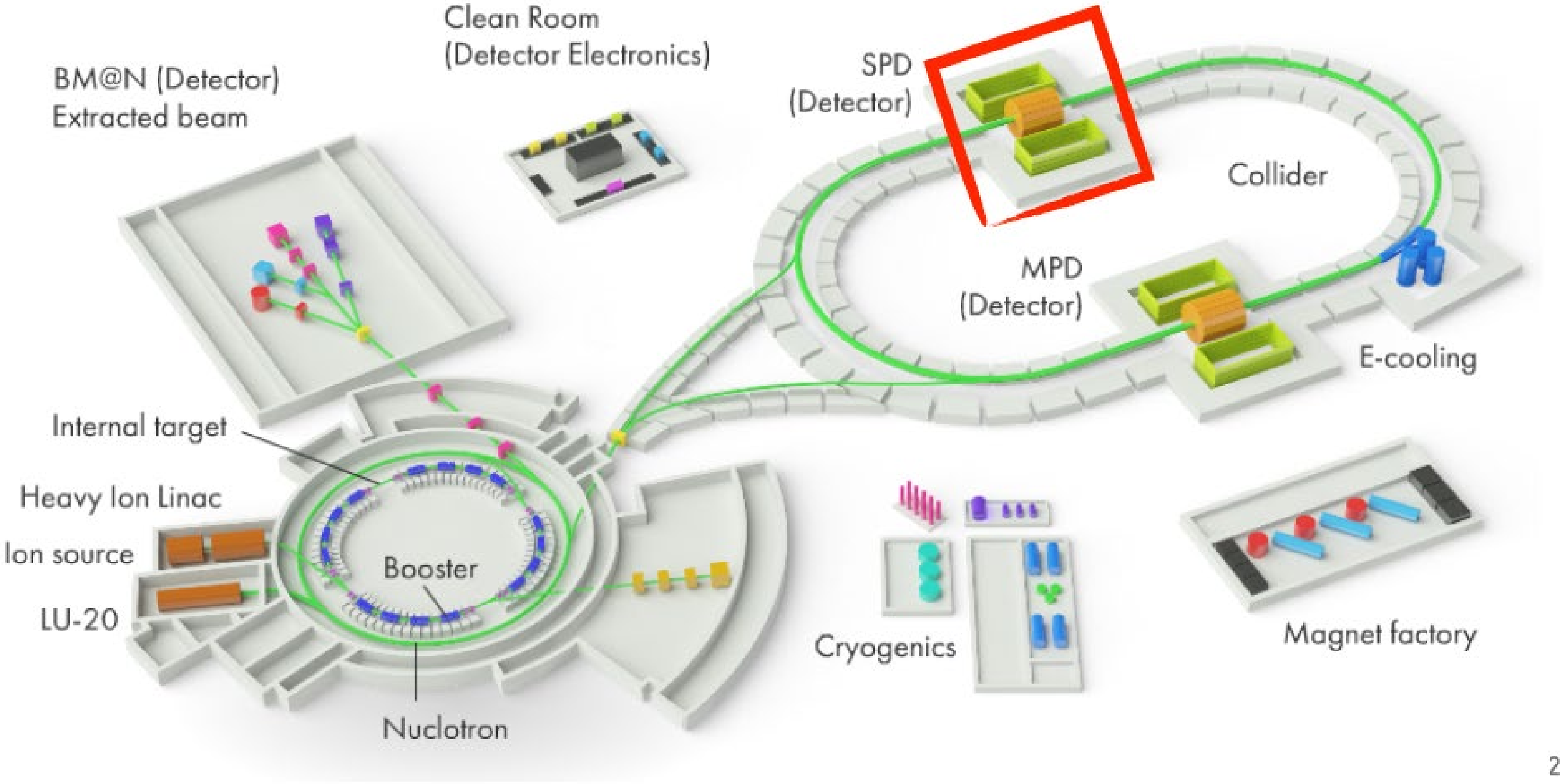
$d^{\uparrow}d^{\uparrow} : \sqrt{s} \leq 13.5\ GeV$

$d^{\uparrow}p^{\uparrow} : \sqrt{s} \leq 19\ GeV$

U, L, T

$|P| > 70\%$

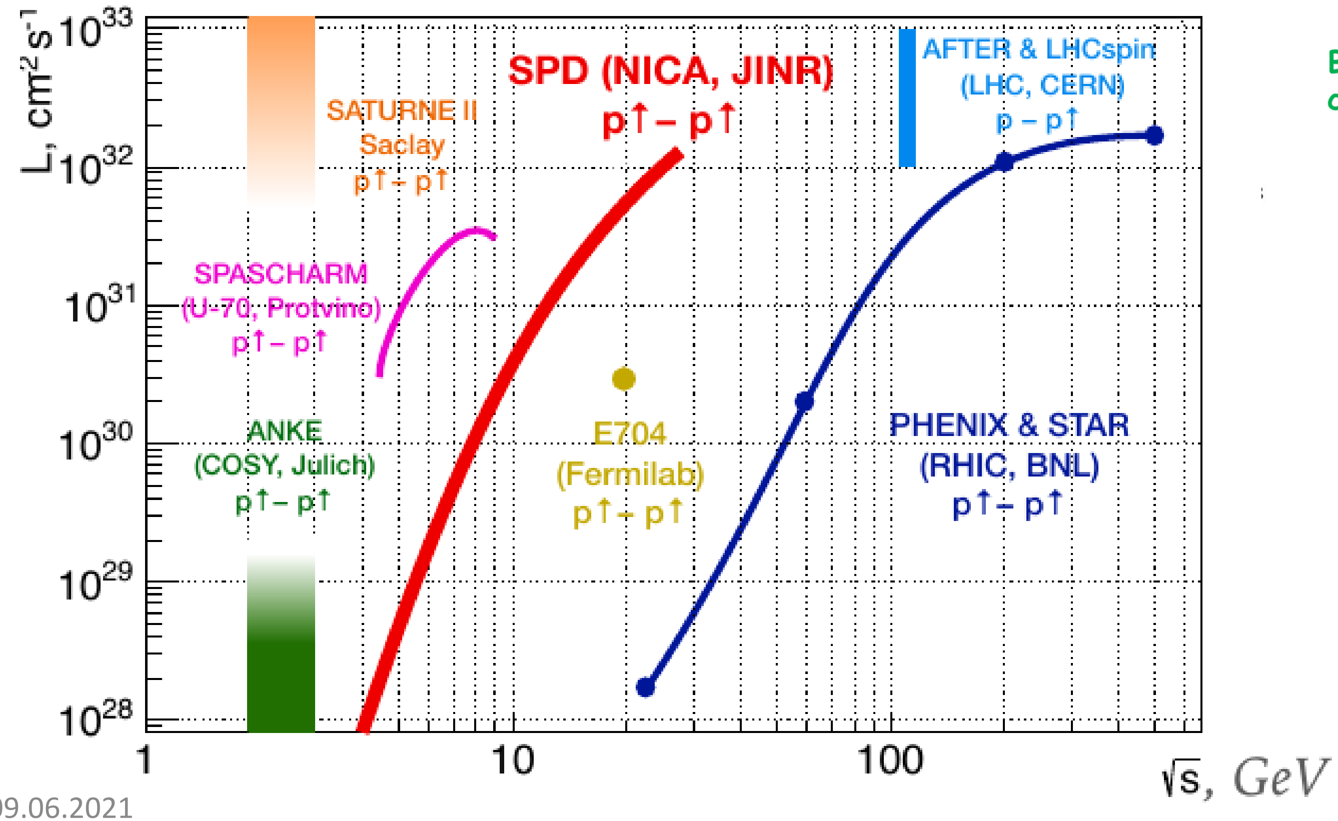




SPD – VS OTHERS

In the $d^{\uparrow}d^{\uparrow}$ mode we are unique

In the $p^{\uparrow}p^{\uparrow}$ mode:



NN Elastic scattering with polarized deuteron beams :

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

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

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

New data!

By the way we will have the counting rules verification!

pd, nd and dd – too!

Main advantages

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

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

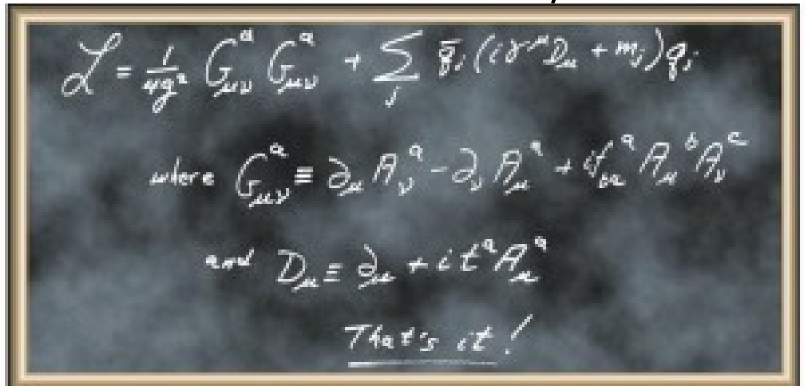
Basics of QCD …

F. Wilczek, QCD Made Simple
Physics Today **53N8** 22-28, (2000)

C.Roberts, NUCLEUS-2020

$$SU_c(3)$$

Quantum Chromodynamics



- Quite possibly, the most remarkable theory we have ever invented
- One line and two definitions are responsible for the

  origin, mass and size of (almost) all visible matter!

…. and SPD NICA

Asymptotic freedom $\Leftrightarrow$ color confinement
Spontaneously broken chiral symmetry

SBCS: at $m_q \to 0$ Global flavor symmetry $SU_L(3)\times SU_R(3)$
Goldstone bosons (π,η,K) **ChEFT** ,
$m_\pi/\Lambda_{CSB}, q/\Lambda_{CSB} \ll 1, \Lambda_{CSB} \sim 1GeV$

MPD NICA: search for phase transitions in AA- collsions (deconfinement, CSR)
The SPD NICA at $\sqrt{s_{NN}} = 3.5 - 10GeV$ *:*
search for transition region $hadrons \to q, g$
(CCR, color transparency, multiquarks, …, phase transitions(?))

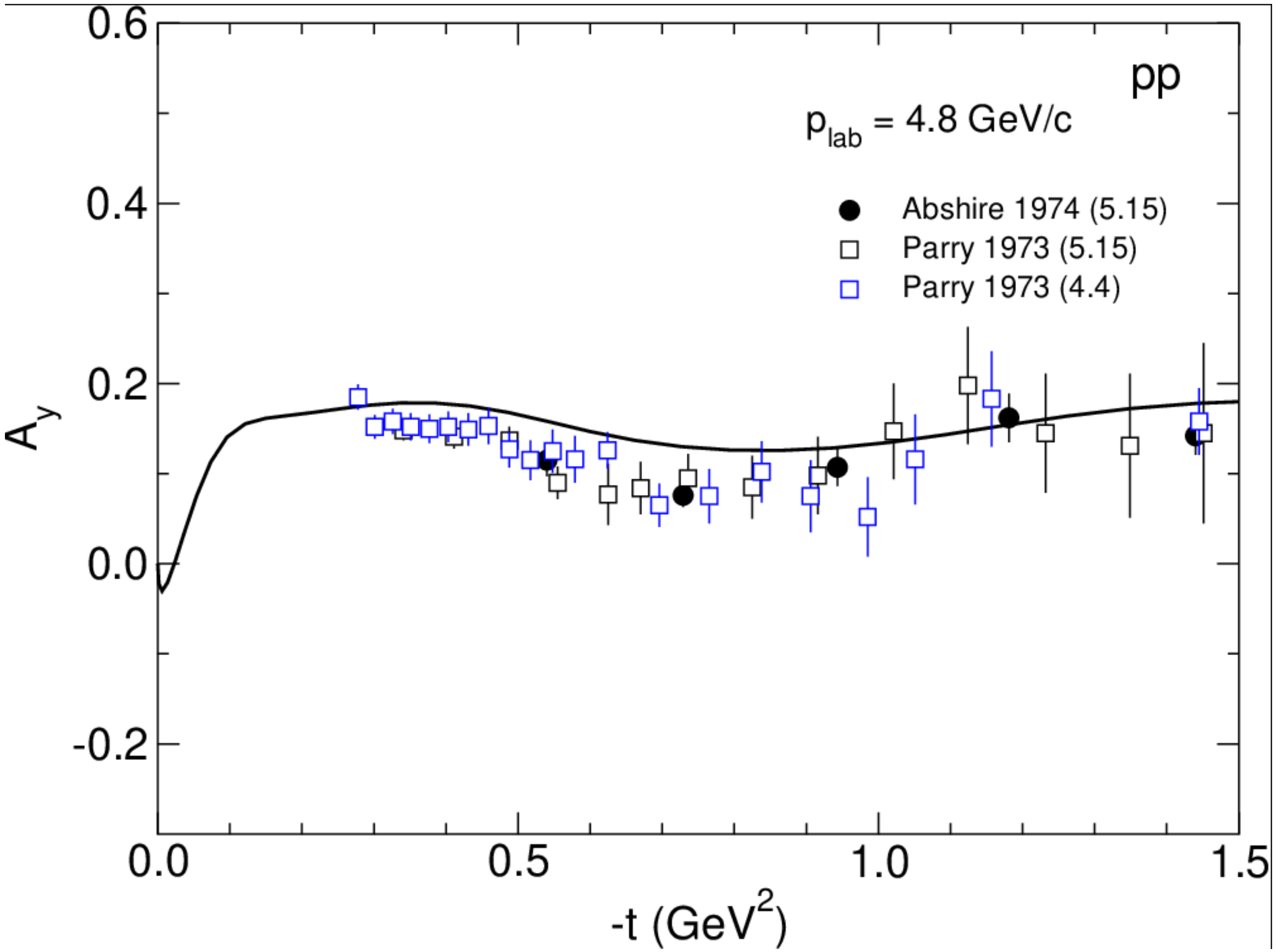
• pN ELASTIC SCATTERING

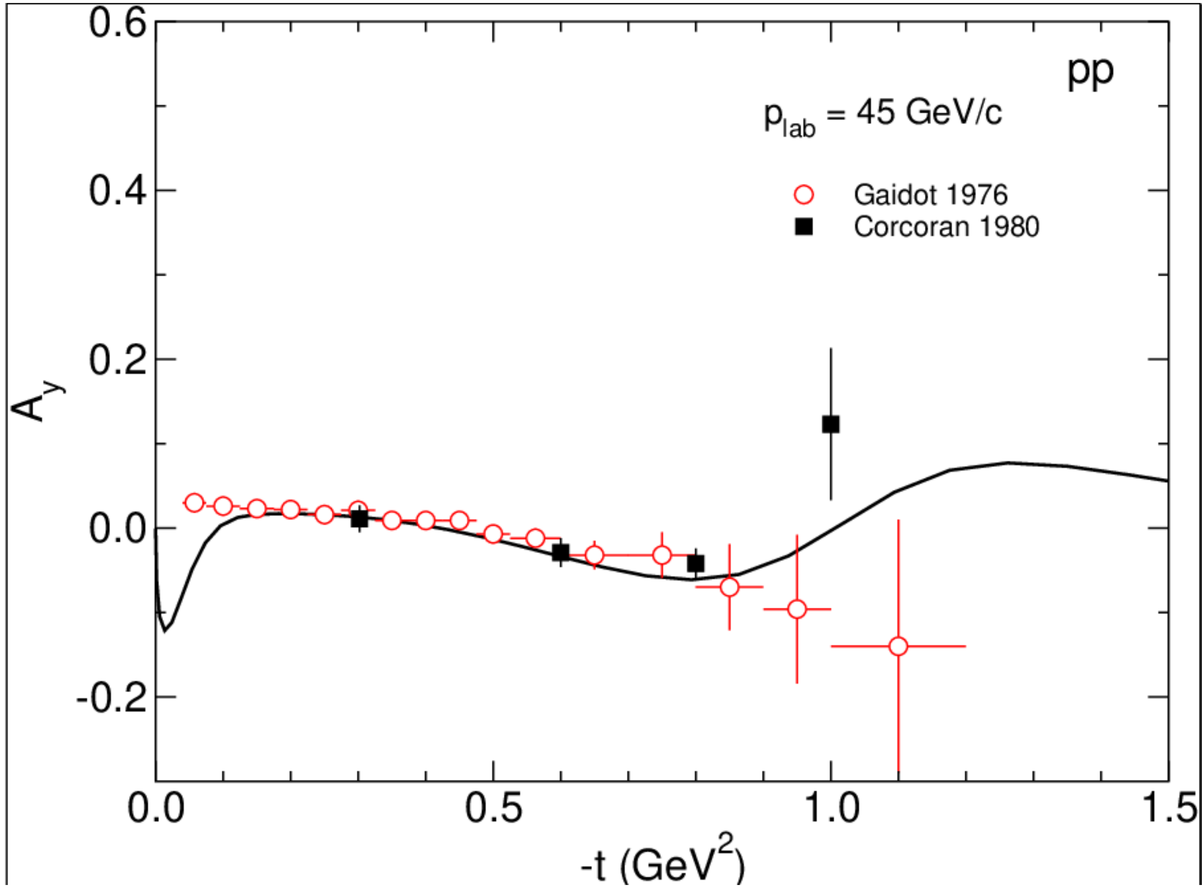
NN forces is a basis of nuclear physics.
NN elastic scattering is a basic process in nuclear reaction
It is important to study all their spin components via measurement of the amplitudes of NN elastic scattering

Soft (small –t,-u) and
Hard (large –t, -u > m_N^2) collisions

A. Sibirtsev et al, EPJA (2010); Regge parametrization of pp amplitudes at p_L=4-5 GeV/c

O. Selugin, PEPAN Letters 13 (2016) 116

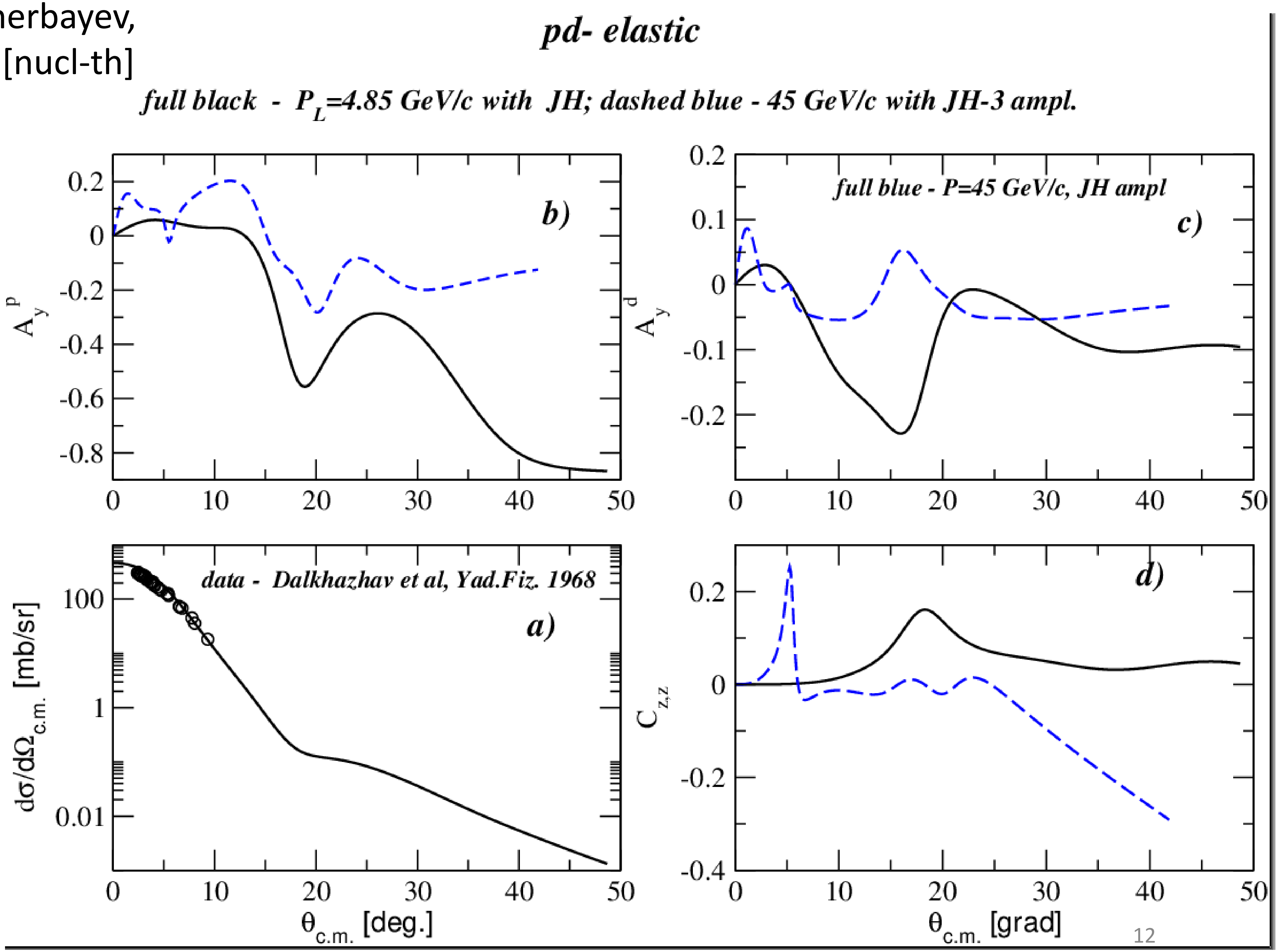


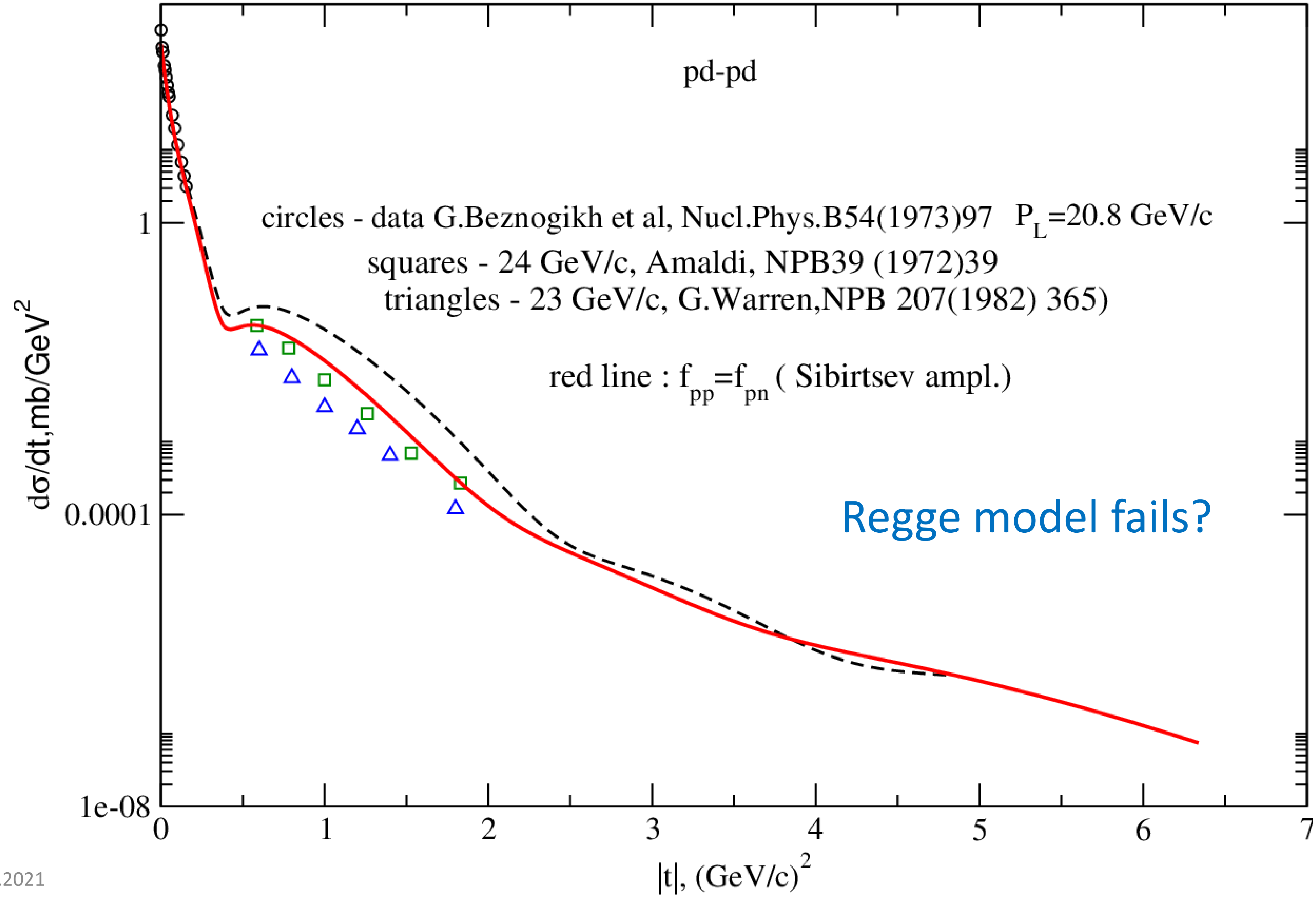


5 helicity pp –amplitudes of pp- scattering $\phi_1, \ldots, \phi_5 \Longrightarrow$ 10 (!) observables
for complete polarization experiment. SAID data base p< 3 GeV/c

Yu.N. U., J. Haidenbauer, A. Temerbayev,
A. Bazarova, arXiv:2011.04304 [nucl-th]
NUCLEUS- 2020

Test of pN amplitudes:
pd elastic scattering
within the Glauber model




pd-pd
circles - data G.Beznogikh et al, Nucl.Phys.B54(1973)97 P_L=20.8 GeV/c
squares - 24 GeV/c, Amaldi, NPB39 (1972)39
triangles - 23 GeV/c, G.Warren,NPB 207(1982) 365)
red line : $f_{pp}=f_{pn}$ (Sibirtsev ampl.)
Regge model fails?
dσ/dt,mb/GeV^2
1
0.0001
1e-08
0
1
2
3
4
5
6
7
|t|, (GeV/c)^2

Quasielastic pd-scattering

$$p + d \to \{pp\}(^1S_0) + n$$

pn->pn: $f_{12}^{collin} = \alpha + \beta(\boldsymbol{\sigma}_1 \cdot \boldsymbol{\sigma}_2) + (\varepsilon - \beta)(\boldsymbol{\sigma}_1 \cdot \mathbf{k})(\boldsymbol{\sigma}_2 \cdot \mathbf{k}).$

$$d\sigma_0 = \frac{1}{3}\mathcal{K}\left\{|\varepsilon|^2 + 2|\beta|^2\right\},$$

$$T_{20} = \frac{1}{\sqrt{2}}A_{zz} = \sqrt{2}\frac{|\beta|^2 - |\varepsilon|^2}{|\varepsilon|^2 + 2|\beta|^2},$$

$$C_{x,x} = C_{y,y} = -2\frac{Re\varepsilon\beta^*}{|\varepsilon|^2 + 2|\beta|^2},\ C_{xz,y} = -C_{yz,x} = 3\frac{Im\beta\varepsilon^*}{|\varepsilon|^2 + 2|\beta|^2}.$$

Complete polarization experiment in collinear kinematics (Yu.N.U):

$$|\varepsilon|, |\beta|, \mathrm{Re}\,\varepsilon\beta^*, \mathrm{Im}\,\varepsilon\beta^*$$

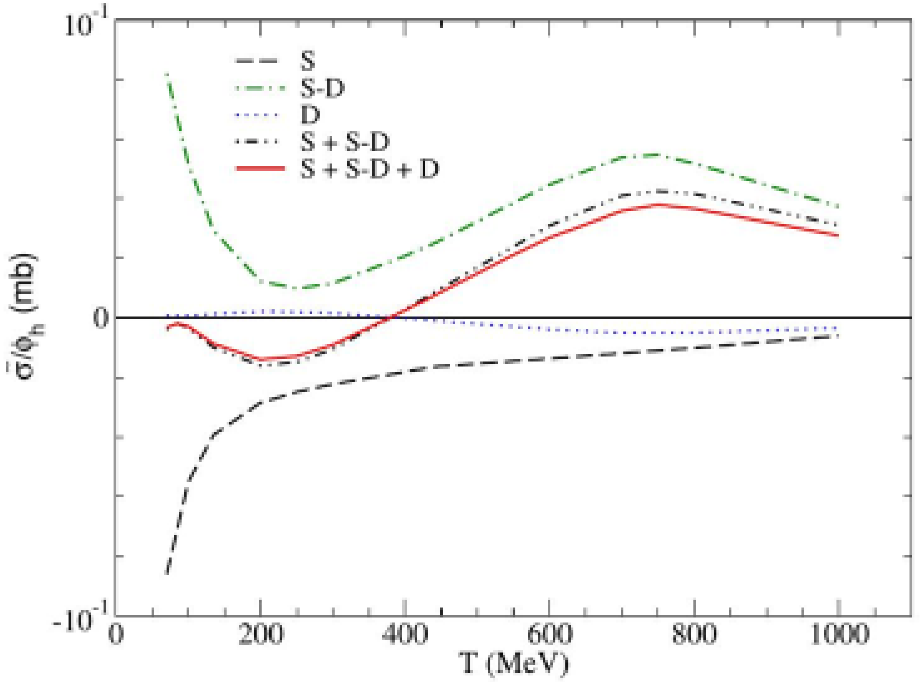
Also dd-elastic and dd->pp($^1S_0$)+nn($^1S_0$)

$$C' \approx i\phi_5 + iq/2m(\phi_1 + \phi_3)/2$$

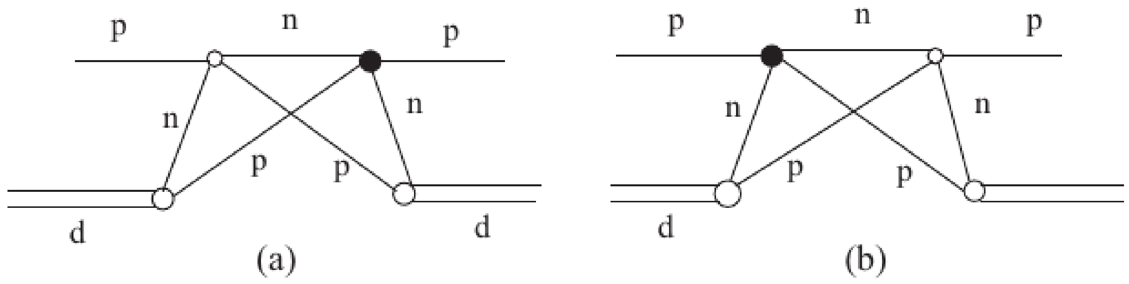
Yu.N.U., A.A. Temerbayev, PRC 92 (2015) 014002;
Yu.N.U., J. Haidenabuer, PRC 94 (2016) 035501.

$$\sigma_{tot} = \underbrace{\sigma_0 + \sigma_1 \mathbf{p}^p \cdot \mathbf{P}^d + \sigma_2(\mathbf{p}^p \cdot \mathbf{k})(\mathbf{P}^d \cdot \mathbf{k}) + \sigma_3 P_{zz}} + \underbrace{\widetilde{\sigma}_{tvpc} p_y^p P_{xz}^d}_{T-odd, P-even}$$

TVPC. The S- and D- wave contributions-I

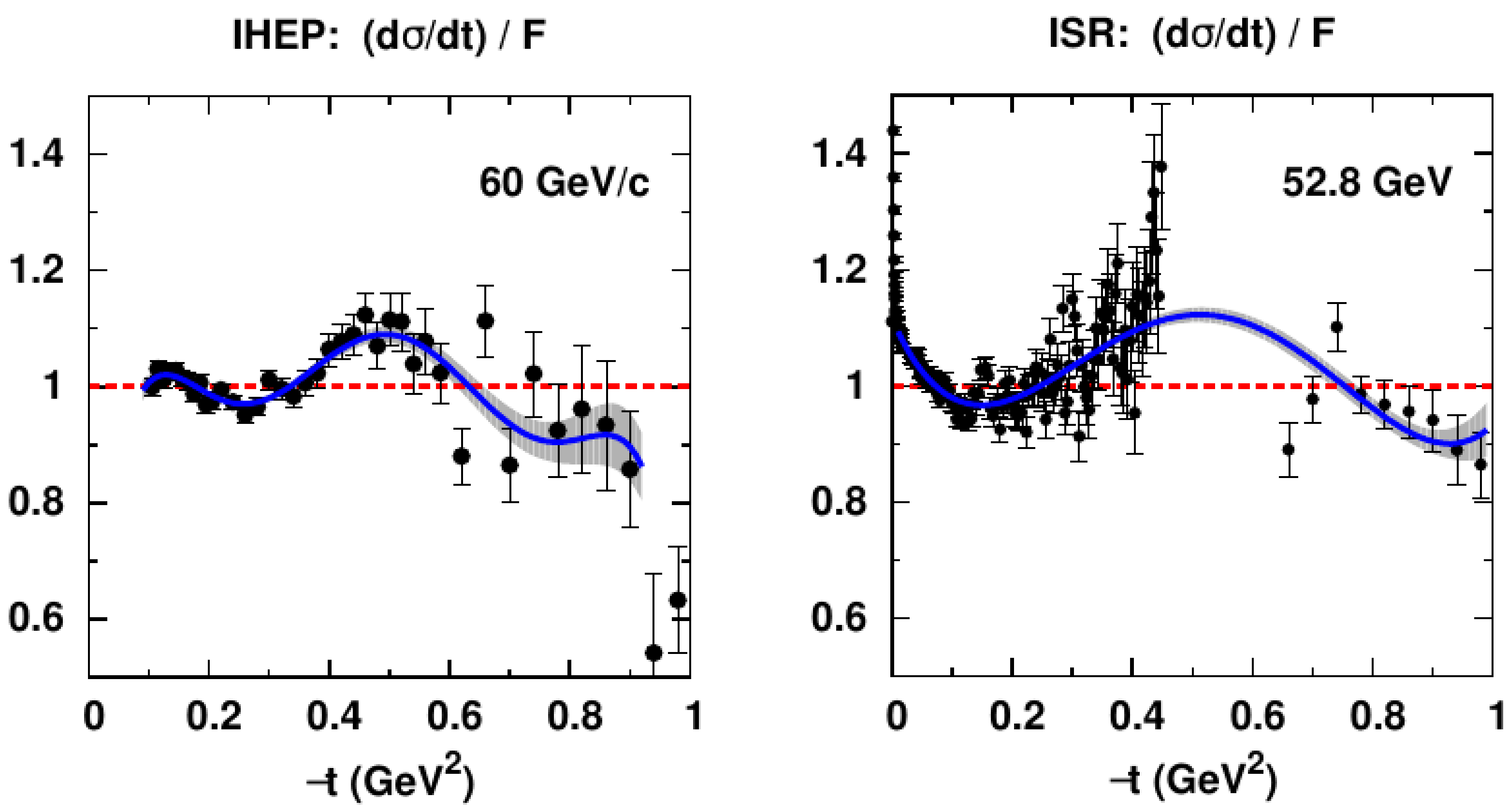


Yu.N. Uzikov, J.Haidenbauer, PRC 94 (2016) 035501



Search for T-invariance violation in double polarized pd – scattering (see also below : N. Nikolaev et al.)

V.A. Baskov, O. D. Dalkarov A. I. L'vov et al.



$$F = Ae^{Bt+ct^2};$$

$$B^{1/2} \sim 0.6\, fm$$

Pion cloud effect,
A.Anselm, V. Gribov (1972);
L. Jenkovsky et al (2018)

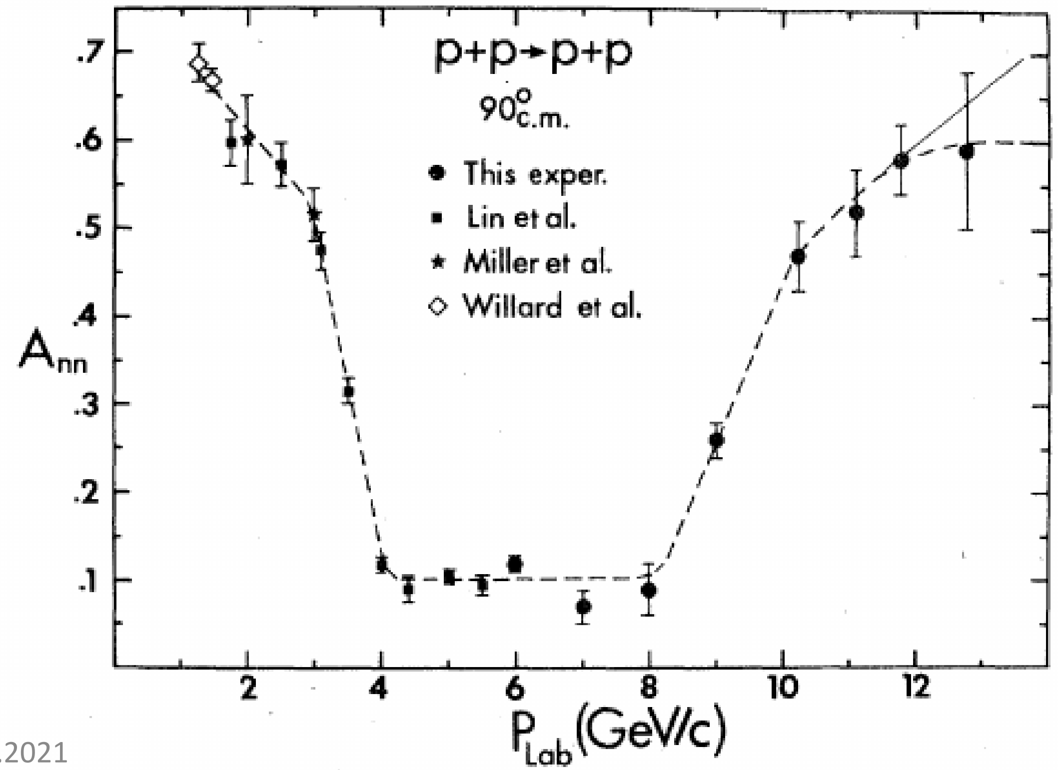
● Spin-spin effects in pp-elastic at $\vartheta_{cm} = 90^{\circ}$

Hard pp elastic scattering

PHYSICAL REVIEW D VOLUME 23, NUMBER 3 1 FEBRUARY 1981

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

E. A. Crosbie, L. G. Ratner, and P. F. Schultz
Argonne National Laboratory, Argonne, Illinois 60439



$$A_{NN} = \frac{d\sigma(\uparrow\uparrow) - d\sigma(\uparrow\downarrow)}{d\sigma(\uparrow\uparrow) + d\sigma(\uparrow\downarrow)}$$

Hard pN elastic scattering

$$\sqrt{s} = 5 - 7 GeV, -t = 5 - 10 GeV^2:$$

$$r_{NN} \sim 1/\sqrt{-t} \leq 0.1 fm$$

Some aspects of QCD dynamics in pp(90°)-elastic:

i) $d\sigma^{pp}(s, \vartheta_{cm} = 90^\circ) \sim s^{-10}$, unexpected oscillations at s=10-20 GeV^2

ii) $A_{NN} = \frac{d\sigma(\uparrow\uparrow) - d\sigma(\uparrow\downarrow)}{d\sigma(\uparrow\uparrow) + d\sigma(\uparrow\downarrow)}$ contradicts to pQCD A_{NN}=1/3

iii) Bump in color transparency in pA -> p+p+(A-1) at $4.9 GeV \leq \sqrt{s_{NN}} \leq 5.5 GeV$

An explanation by Brodsky@de Teramond(1988) : octoquarks at the threshold $s\bar{s}, c\bar{c}$

$$\phi_2^{PQCD} = \phi_5^{PQCD} = 0;$$

$$\sigma A_{NN} = |\phi_3|^2; \sigma = 3|\phi_3|^2; A_{NN}^{pQCD} = \frac{1}{3}$$

Octoquark resonances: $J = L = S = 1$ $\quad uuds\bar{s}uud \quad \sqrt{s} = 3GeV$

$uudc\bar{c}uud \quad \sqrt{s} = 5GeV \quad pp \to p[J/\psi p]$

Future data on A_{NN} in pn-pn elastic scattering will be very important to get more insight into this issue due to different spin-isospin dependence of p-n (T=0) as compared to p-p.

This can be done at NICA SPD.

What is relation to LHCb pentaquarks from decay of ? $\Lambda_b \to J/\psi p$

• COLOR TRANSPARENCY

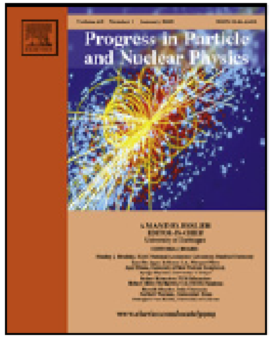
Progress in Particle and Nuclear Physics 69 (2013) 1–27

Contents lists available at SciVerse ScienceDirect

Progress in Particle and Nuclear Physics

journal homepage: www.elsevier.com/locate/ppnp

ELSEVIER



Review

Color transparency: Past, present and future

D. Dutta [a,*], K. Hafidi [b], M. Strikman [c]

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

A.H. Mueller,1982;
S. Brodsky, 1982

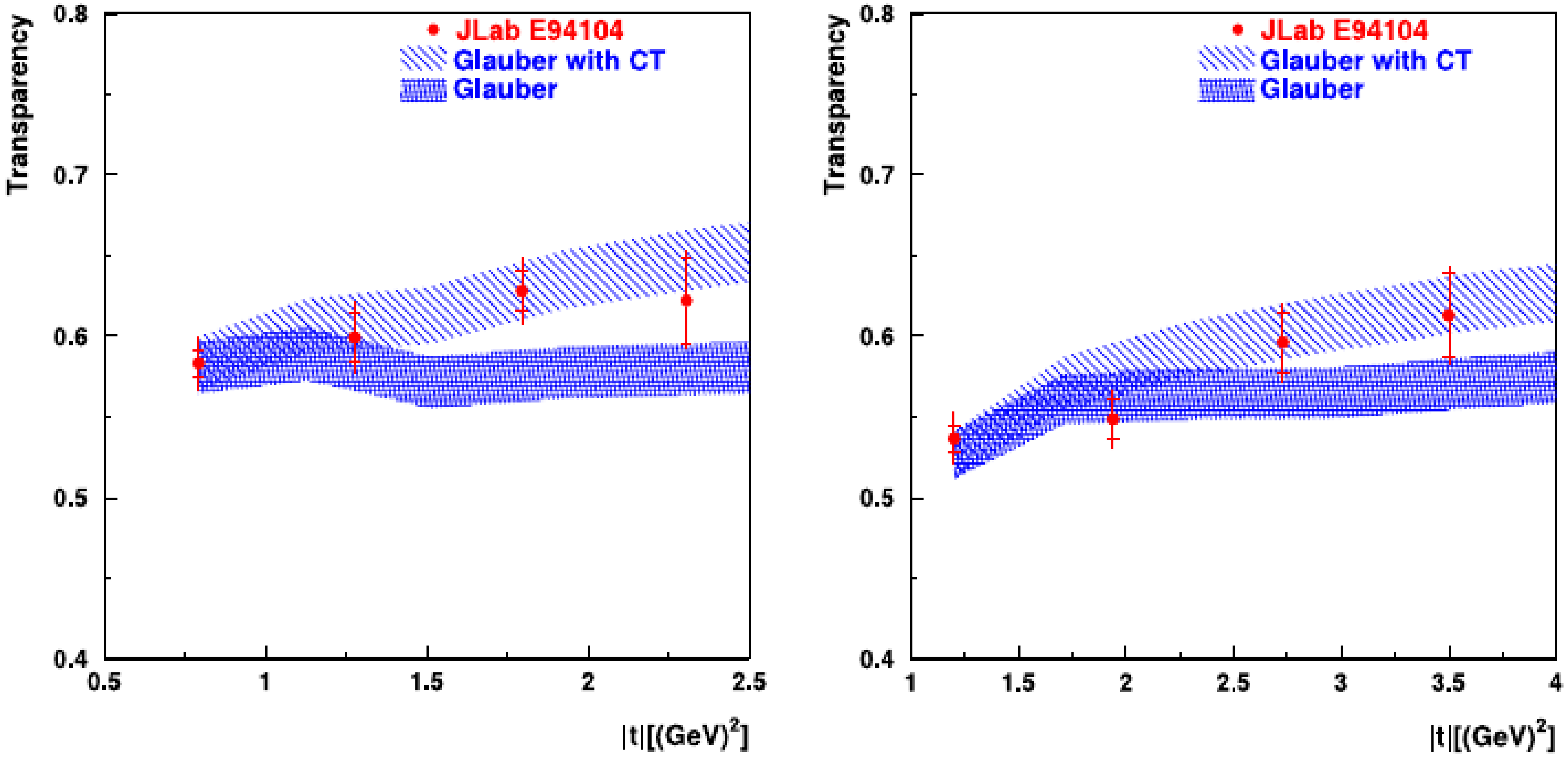
In the limit of very small configurations in the projectile giving dominant interaction should be small leading to

$$\sigma(h + A \to h + N + (A-1)) = A\sigma(h + N \to h + N)$$

referred to as color transparency (CT)

Observation of CT was suggested as a test of the origin of elastic large angle scattering by A.Mueller and S.Brodsky

Problem is that to reach the regime where $L_h > 2R_A$ where one expect to observe 100% CT one needs very large s where cross sections are very small + only proton beams are doable



For baryons CT observations are less clear –bump.

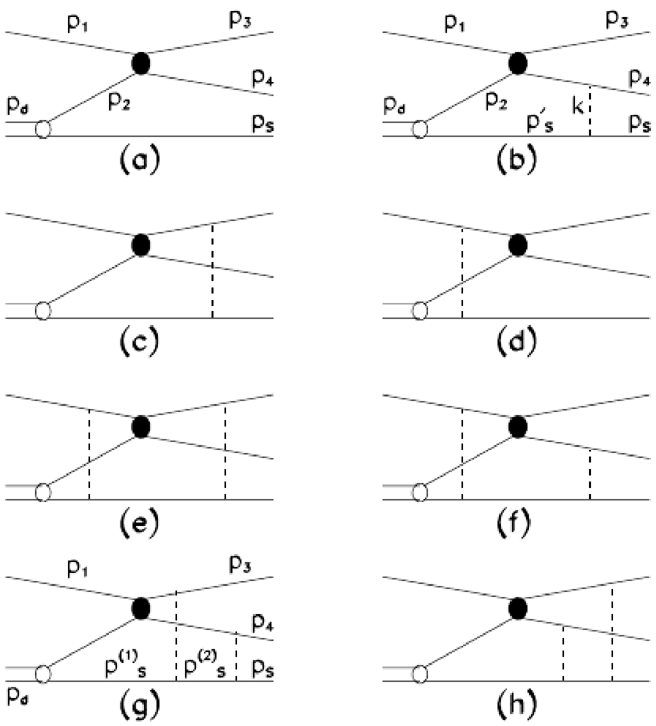
Fig. 13. The nuclear transparency of ^{4}He(γ, $p\pi$) at $\theta^{\pi}_{cm} = 70°$ (left) and $\theta^{\pi}_{cm} = 90°$ (right), as a function of momentum transfer square $|t|$ [80]. The inner error bars shown are statistical uncertainties only, while the outer error bars are statistical and point-to-point systematic uncertainties (2.7%) added in quadrature. In addition there is a 4% normalization/scale systematic uncertainty which leads to a total systematic uncertainty of 4.8%.

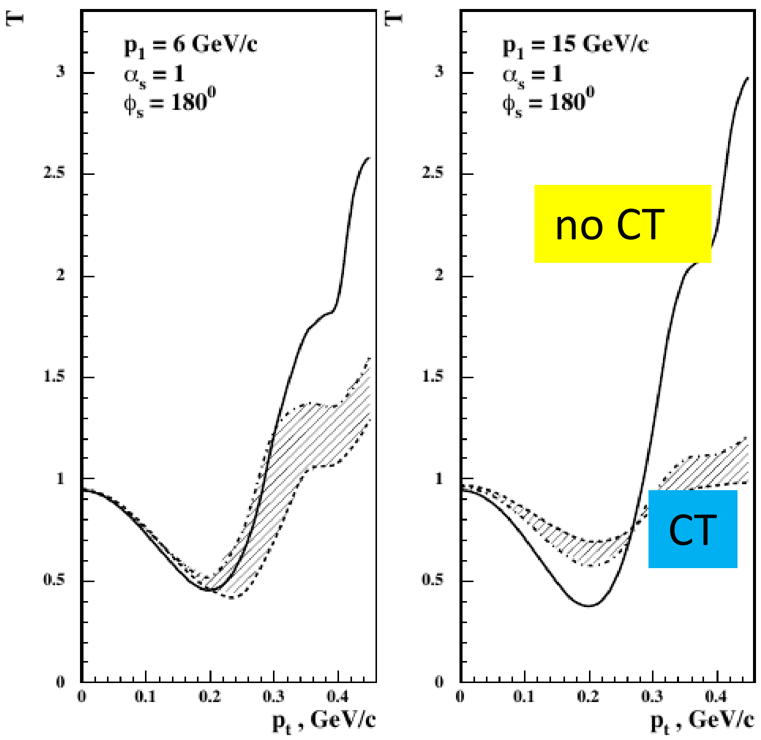
Testing rescattering dynamics (including color transparency effects - dashed curves)

L.L. Frankfurt et al. PRC 56 (1997)

$$T = \sigma^{DWIA} / \sigma^{IA}$$

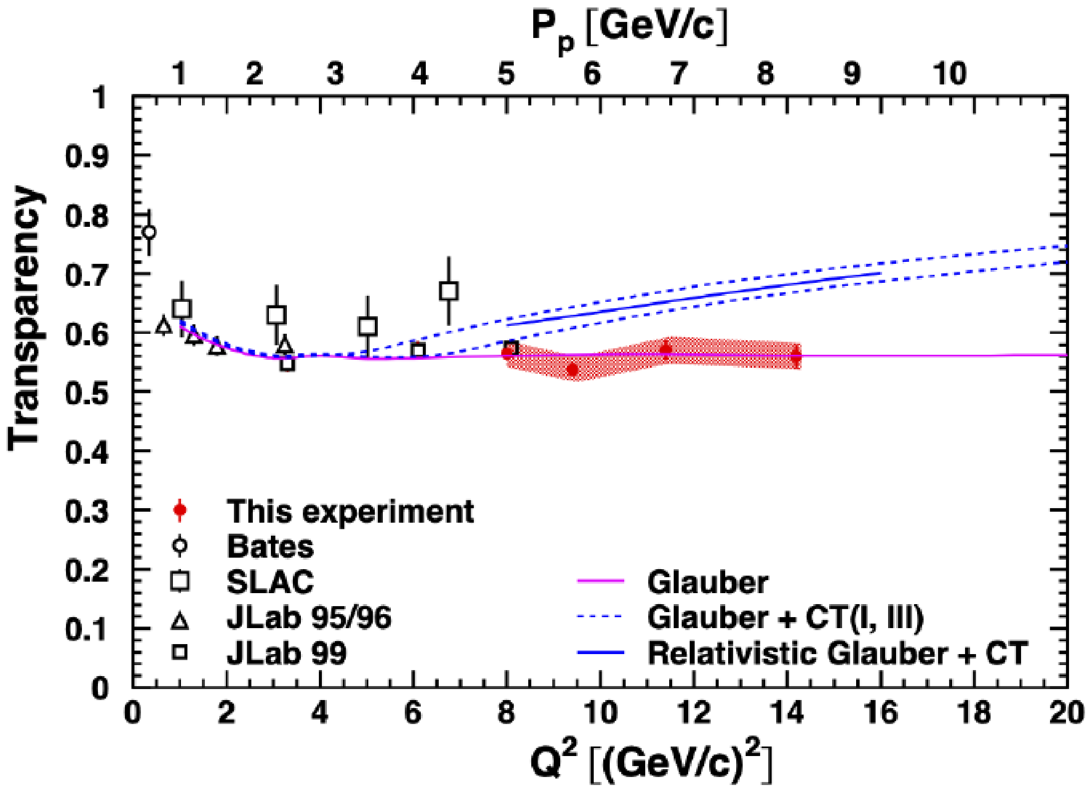
pd->ppn





α_s =1 optimal for testing dynamics of multinucleon rescatterings

A NEW PROBLEM



D. Bhetuwal et al (Hall C), PRL 126 (2021) 082301
“Ruling out color transparency in quasi-elastic $^{12}C(e,e'p)$ up to Q^2 =14.2 [GeV/c]^2”,

See also contribution by A. Larionov on CT in ^{12}C-^{12}C and Ca-Ca collisions

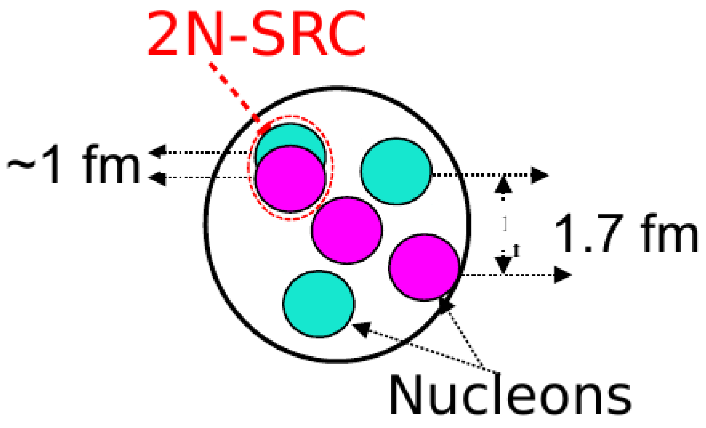
Quasielastic $^{12}C(e,e'p)$ scattering was measured at negative 4-momentum transfer squared $Q^2 = 8$, 9.4, 11.4, and 14.2 $(\mathrm{GeV/c})^2$, the highest ever achieved to date. Nuclear transparency for this reaction was extracted by comparing the measured yield to that expected from a plane-wave impulse approximation calculation without any final state interactions. The measured transparency was consistent with no Q^2 dependence, up to proton momentum scales where earlier $A(p,2p)$ results had indicated a rise in transparency, ruling out the quantum chromodynamics effect of color transparency at the measured Q^2 scales. These results impose strict constraints on models of color transparency for protons.

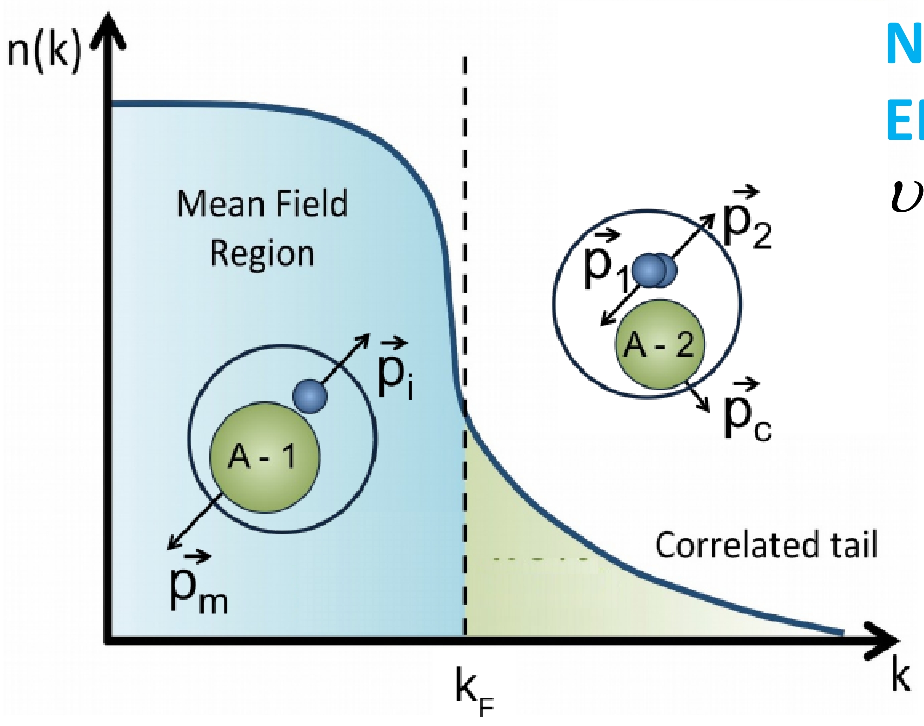
Short-Range Correlations (SRC) in Nuclei

- SRC pair: 2N in close proximity

  In momentum space:
  - Large relative momentum (> k_F)
  - Smaller center-of-mass motion

- here: $^{12}C(p,2p\ ^{10}B)n$, $^{12}C(p,2p\ ^{10}Be)p$





V_{NN}
Neutron stars
EMC
$\upsilon - A$

R. Subedi et al., Science (2008)
O. Hen et al., Science (2014)
M. Duer et al., Nature (2018)
E. Cohen et al., PRL (2018)

Summary of the theoretical analysis of the experimental findings

practically all of which were predicted well before the data were obtained

Ladygin V. P.
06.10.2020

More than ~90% all nucleons with momenta $k \geq 300$ MeV/c belong to two nucleon SRC correlations BNL + Jlab +SLAC

Probability for a given proton with momenta $600 > k > 300$ MeV/c to belong to **pn** correlation is ~ 18 times larger than for **pp** correlation BNL + Jlab

Probability for a nucleon to have momentum > 300 MeV/c in medium nuclei is ~25% BNL + Jlab 04 +SLAC 93

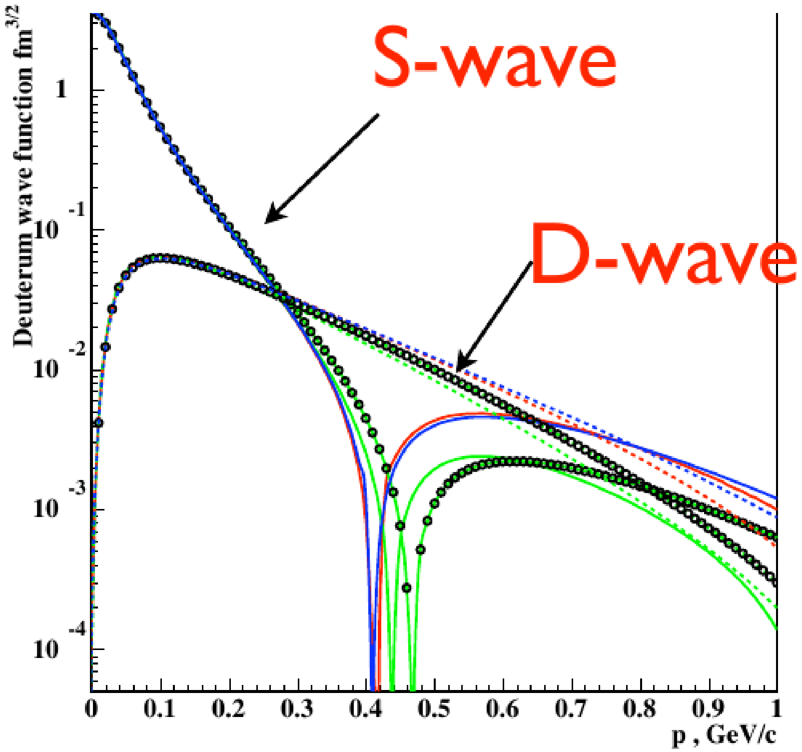
Probability of non-nucleonic components within SRC is small - < 20% - 2N SRC mostly build of two nucleons not 6q, $\Delta\Delta$,... BNL + Jlab +SLAC

Three nucleon SRC are present in nuclei with a significant probability Jlab 05

Poor data on spin properties of 2N and 3N SRC

Deuteron structure at short distances and SRC in A

Deuteron is a hydrogen atom of short range nuclear structure studies



$$\psi_D^2(k)_{|k\to\infty} \propto \frac{V_{NN}^2(k)}{k^4}$$

D-wave dominates in the Deuteron wf
for 300 MeV/c < k < 700 MeV/c

D-wave is due to tensor forces which are much more important for pn than pp

$i=1$

$$n_A(k)_{|k\to\infty} \propto \frac{V_{NN}^2(k)}{k^4}$$

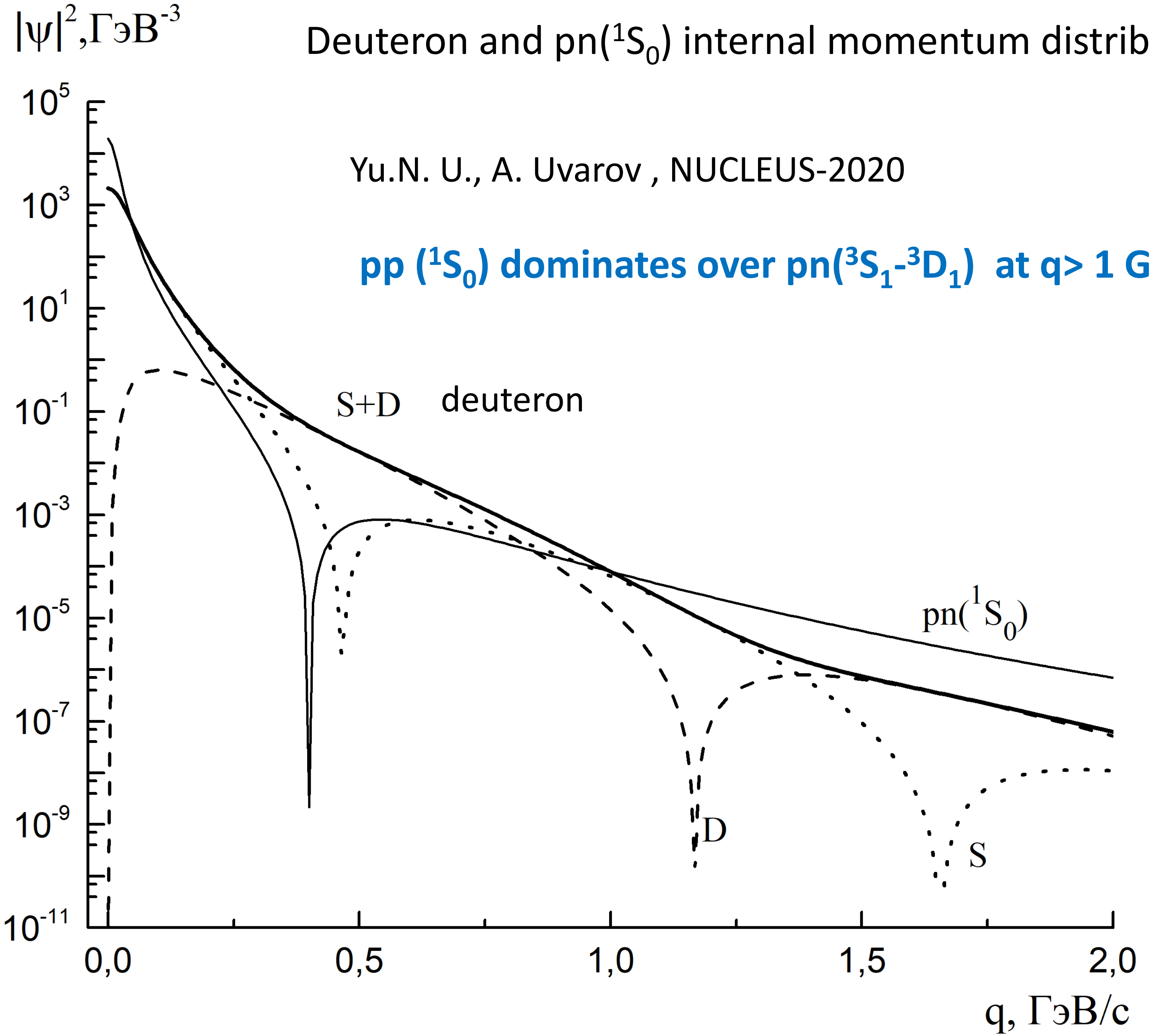
$$\Longrightarrow n_A(k) \approx a_2(A)\psi_D^2(k)_{|k\to\infty}$$

O. Hen, G. Miller, E. Piasetzky,
Rev. Mod. Phys. 89 (2017)

Deuteron and pn($^1S_0$) internal momentum distribution

Yu.N. U., A. Uvarov , NUCLEUS-2020

pp ($^1S_0$) dominates over pn($^3S_1$-$^3D_1$) at q> 1 GeV/c



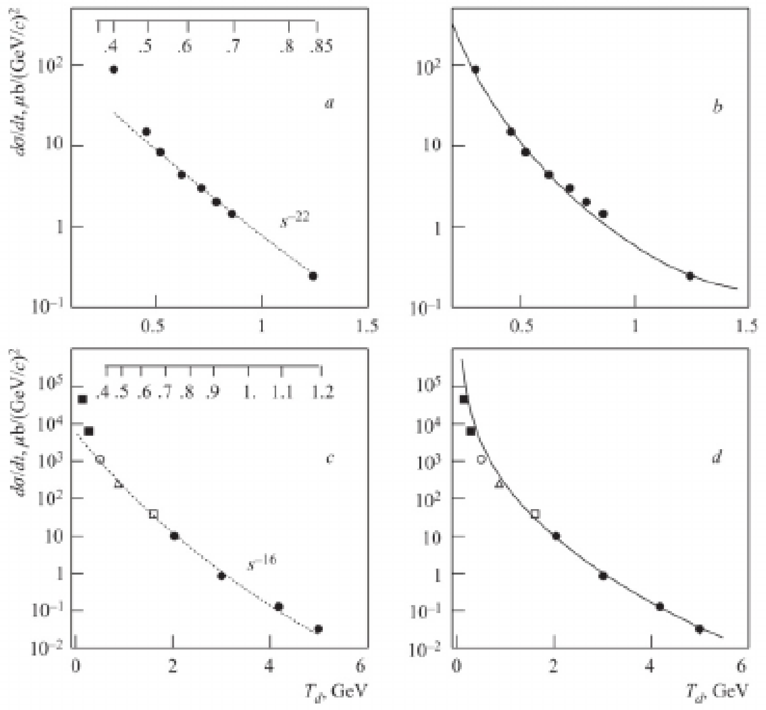
CONSTITUENT COUNTING RULES (CCR)

At high energy s and large transverse momenta p_t the constituent counting roles (CCR) predict the following behavior of the differential cross section for the binary reactions:

$$\frac{d\sigma}{dt}(ab \to cd) = \frac{f(t/s)}{s^{n-2}} \quad ; \quad n = N_a + N_b + N_c + N_d$$

Ladygin V. P.
06.10.2020

Matveev, Muradyan, Tavkhelidze -self similarity
Brodsky, Farrar et al. -perturbative QCD
J. Polchinski, M.J. Strassler -AdS/QCD correspondance



Yu. N. Uzikov , JETP Lett, 81 (2005) 303-306

For the reaction **dd → ³Hen**

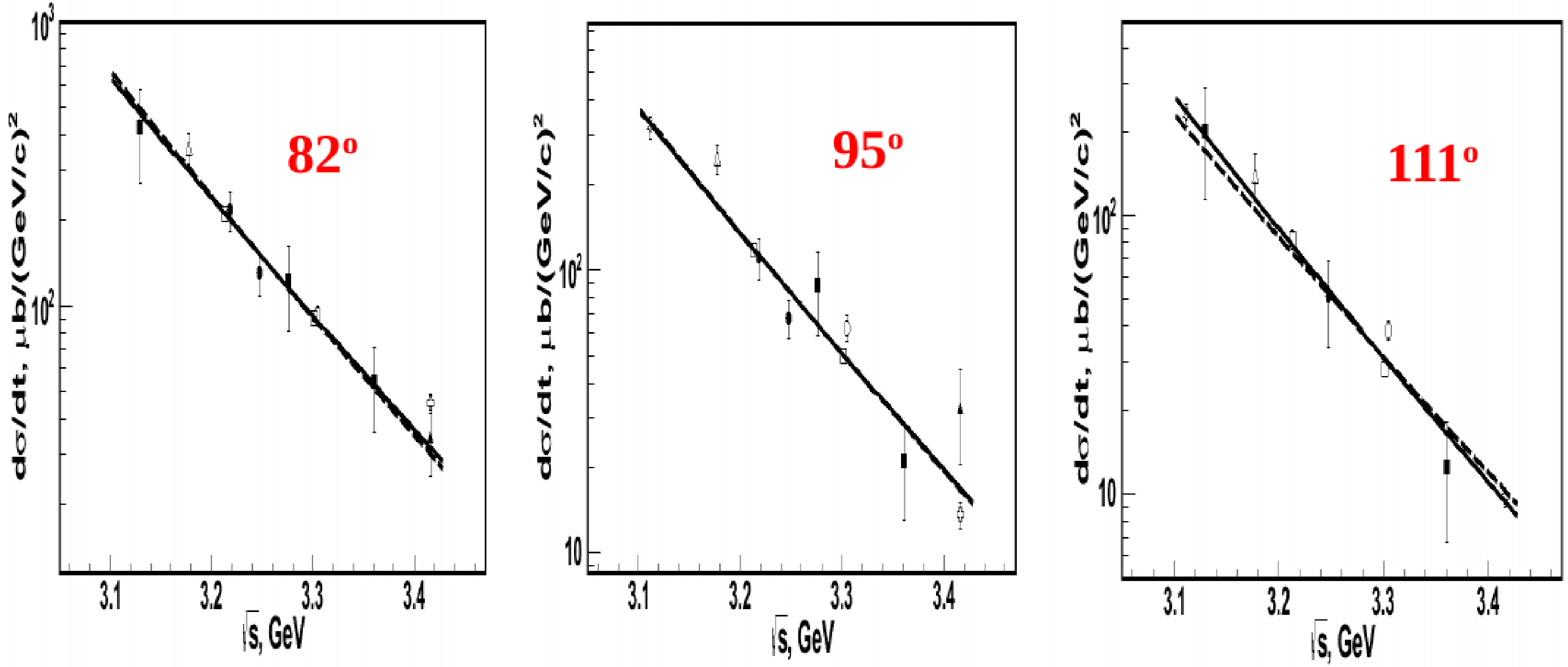
$$N_A + N_B + N_C + N_D - 2 = 22$$

For the reaction **dp → dp**

$$N_A + N_B + N_C + N_D - 2 = 16$$

The regime corresponding to CCR can occur already at $T_d \sim 500$ MeV

CCR for dp- elastic scattering cross section



Pictures are taken from A.A.Terekhin et al., Eur.Phys.J, A55 (2019) 129

Lines are the results of the fit by the S^{-16} (dashed) and S^{-n}(solid) dependencies.

Multiparton interaction and exotic resonance production

Victor Kim

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in collaboration with A.A. Shavrin (SPbSU) and A.V. Zelenov (NRC KI - PNPI)

$$pp \to d(\vartheta_{cm} = 90^o) + X$$

Search for dibaryon resonances
V.I. Komarov (2018)

B. Kostenko: d+d->d+d*

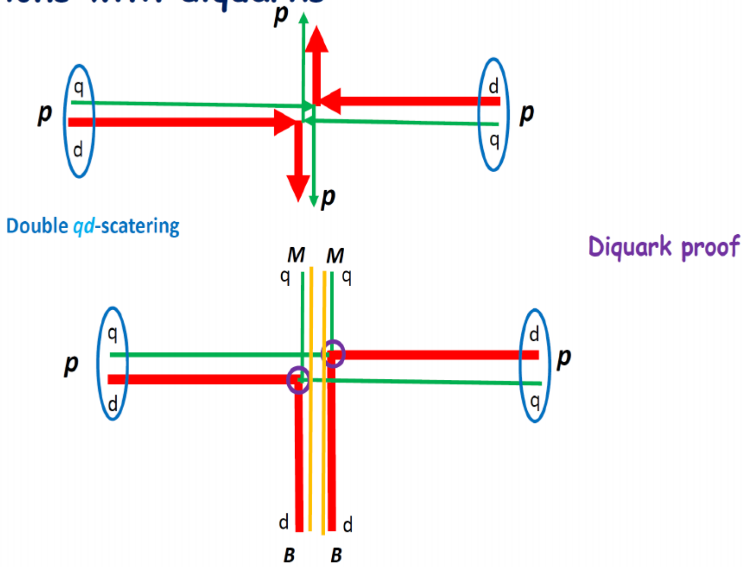
$$q_0 = \frac{M_*^2 - M_d^2}{4E_d^{lab}}, M_* = M_d + n\varepsilon$$

Ratio d/p

Kim's mechanisms in exclusive reactions

NICA SPD

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



VECTOR MESONS PRODUCTION IN *NN* COLLISIONS

(F.E. Tomasi-Gustafsson)

$$N+N \to N+N+V,\ V=\rho,\omega,\phi,\ J/\Psi\ldots$$

General Considerations for threshold production
(the threshold region may be quite wide : $q< m_c$)

$$S_i = 1,\ \ell_i = 1\ \to\ j^P = 1^- \to S_f = 0,$$
$$\mathcal{M}(\mathrm{pp}) = 2f_{10}[\tilde{\chi}_2\sigma_y\vec{\sigma}\cdot(\vec{U}^*\times\hat{\vec{k}})\chi_1]\,(\chi_4^\dagger\sigma_y\,\tilde{\chi}_3^\dagger),$$

$$S_i = 1, \ell_i = 1 \to j^P = 1^- \to S_f = 0,$$
$$S_i = 0, \ell_i = 1 \to j^P = 1^- \to S_f = 1,$$
$$\mathcal{M}(\mathrm{np}) = f_{10}[\tilde{\chi}_2\sigma_y\vec{\sigma}\cdot(\vec{U}^*\times\hat{\vec{k}})\chi_1](\chi_4^\dagger\sigma_y\,\tilde{\chi}_3^\dagger) + f_{01}(\tilde{\chi}_2\,\sigma_y\chi_1)[\chi_4^\dagger\vec{\sigma}\cdot(\vec{U}^*\times\hat{\vec{k}})\sigma_y\tilde{\chi}_3^\dagger],$$

The dynamical information is contained in the amplitudes that are different for the different vector mesons

M.P. Rekalo, E.T.-G.. New J. Phys., 4,68(2002).

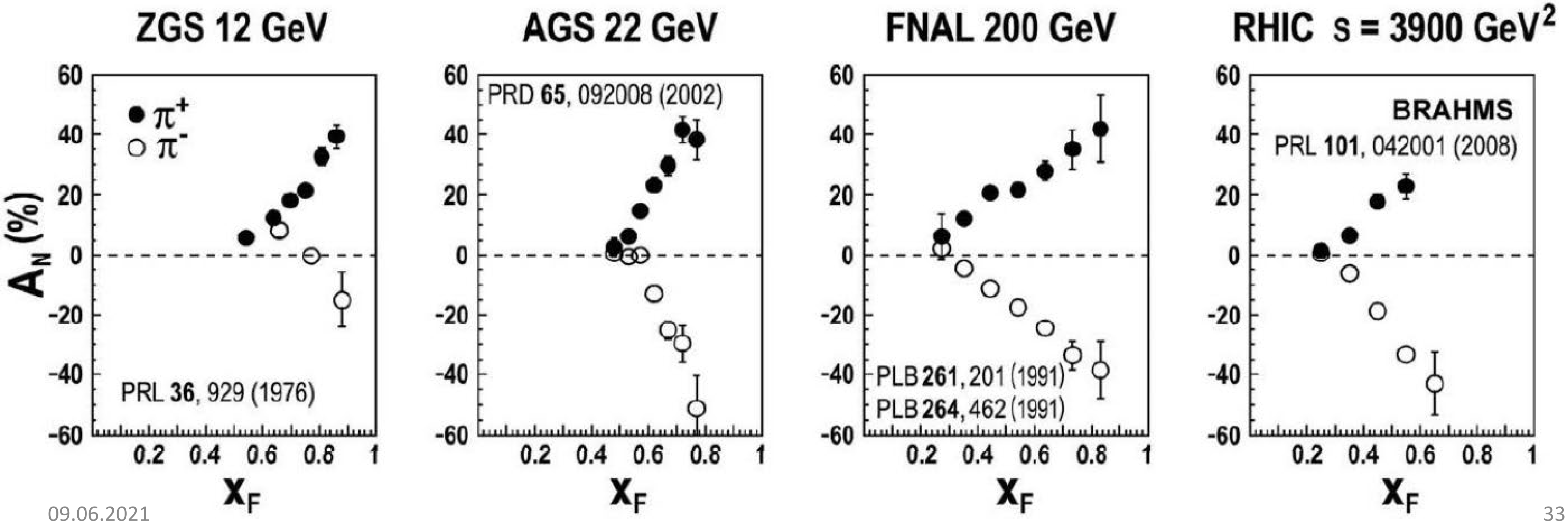
- *Large isotopic effects at threshold*

$$\frac{\sigma(np\to npJ/\psi)}{\sigma(pp\to ppJ/\psi)} = 5.$$

pQCD does not explain single and double spin asymmetries in $pp \to \pi^+(\pi^-)X$

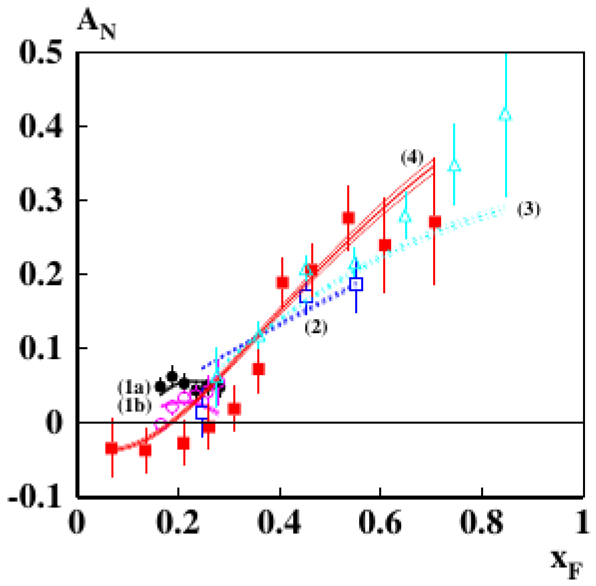
INCLUSIVE PION ASYMMETRY IN PROTON-PROTON COLLISIONS

C. Aidala SPIN 2008 Proceeding and CERN Courier June 2009

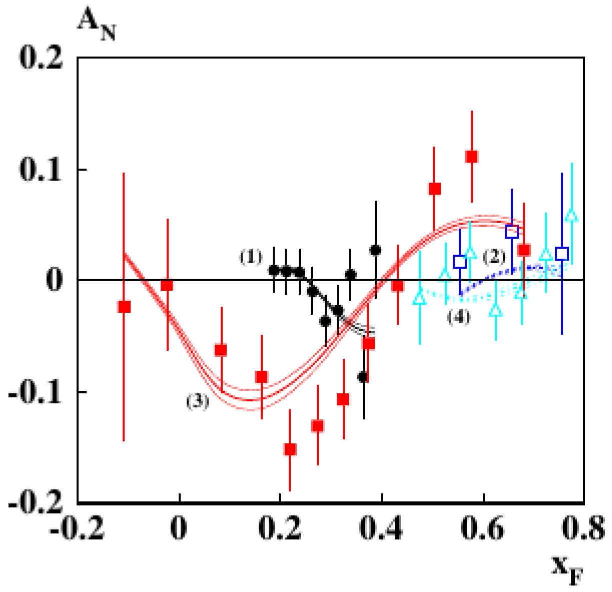


5. Single-spin physics

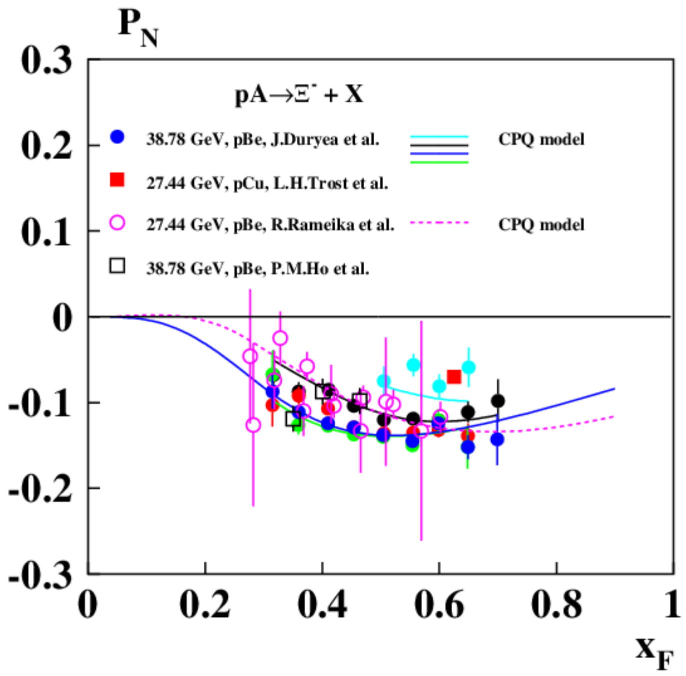
The model of chromomagnetic polarization of quarks (CPQ) , V. Abramov, 2009-2020



(a)



(b)



$A_N(x_F)$ for the reaction $p^{\uparrow} + p(A) \to \pi^+ + X$ **(a)** and $p^{\uparrow} + p(A) \to p + X$ [102] **(b)** [102].

$$\lambda \approx -|\psi_{qq}(0)|^2/|\psi_{q\bar{q}}(0)|^2 = -1/8 = -0.125.$$

中国科学院高能物理研究所 Institute of High Energy Physics

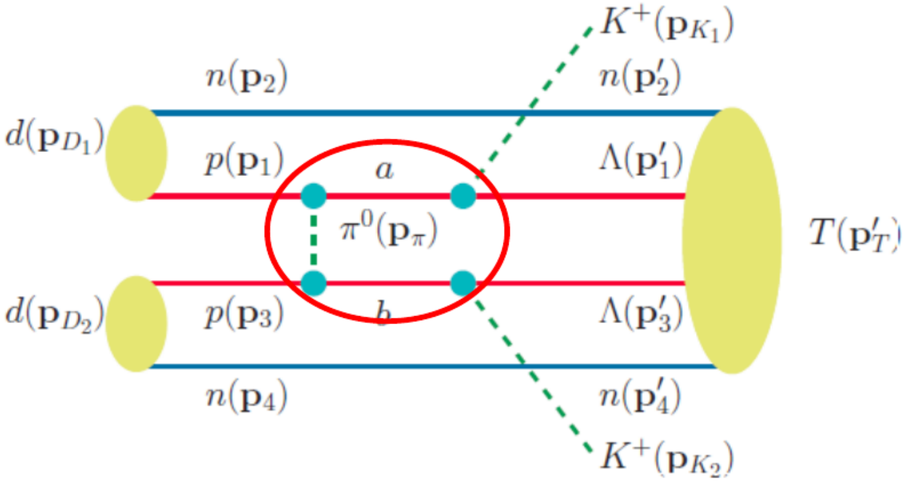
中国科学院 CHINESE ACADEMY OF SCIENCES

Production of the neutral hyper-nucleus ${}^{4}_{\Lambda\Lambda}n$ at SPD NICA

Qiang Zhao

Production mechanism for (ΛΛnn) in deuteron-deuteron collision

$$d + d \to K^+ + K^+ + T.$$



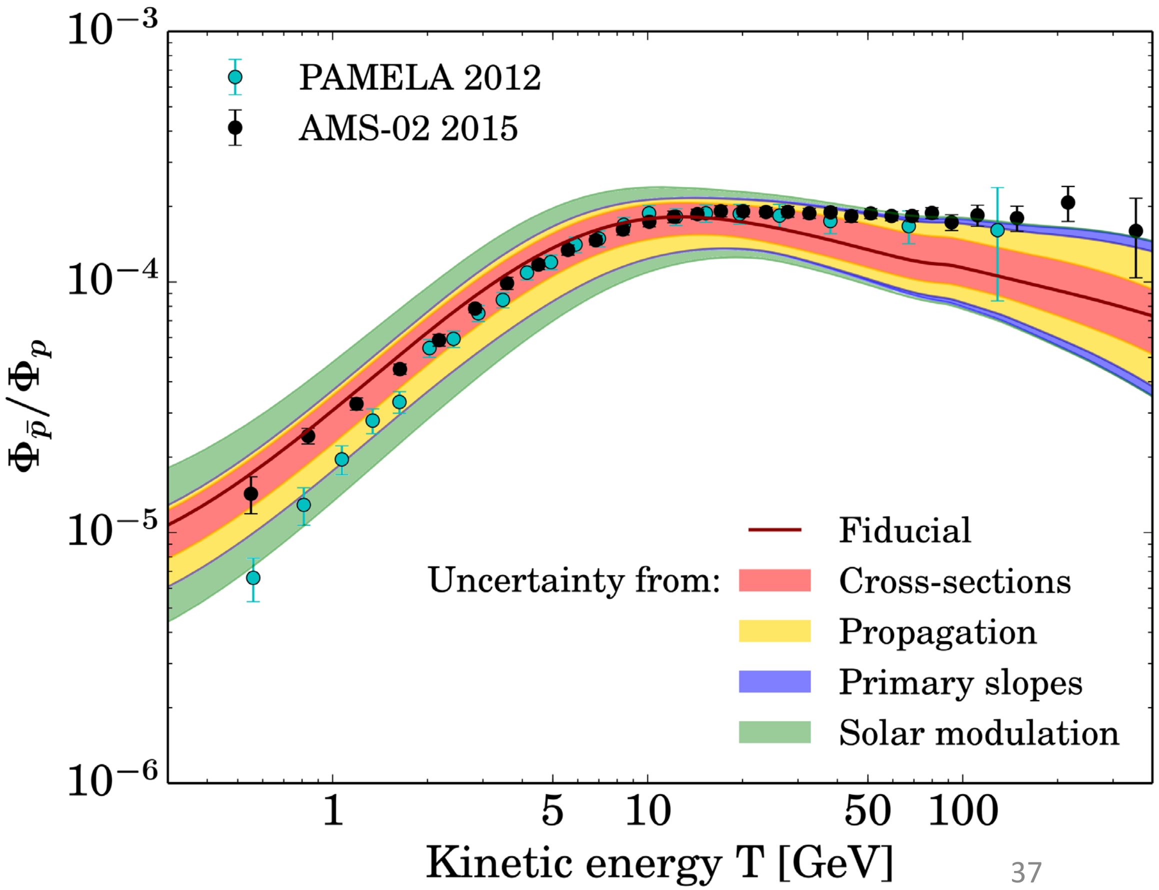
J.M. Richard, Q. Wang, Q. Zhao, PRC 91 (2015) 014003

- SEARCH FOR PHYSICS BEYOND THE STANDARD MODEL

Measuring Antiproton-Production Cross Sections for Dark Matter Search (Reham El-Kholy)

DM in light of AMS-02 measurements

- Dark matter > 26%
- AMS-02: Potential signal at m_{DM}~80 GeV
- High theoretical uncertainties: 20-50%[1]
- Stat. sig.: from (> 5σ) to (~ 1.1σ)

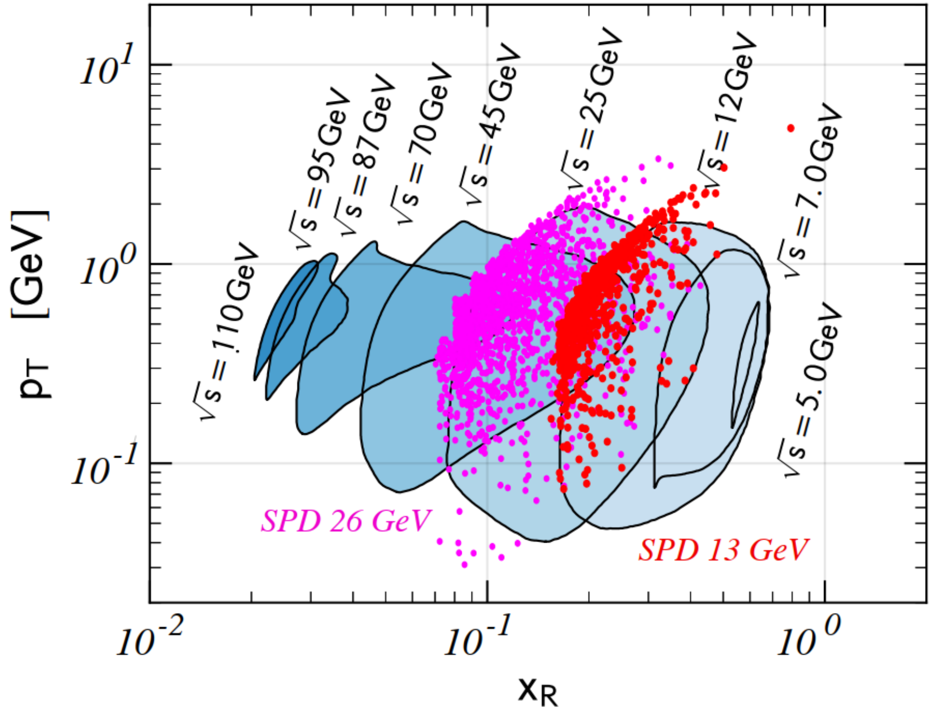


Potential Coverage by NICA SPD

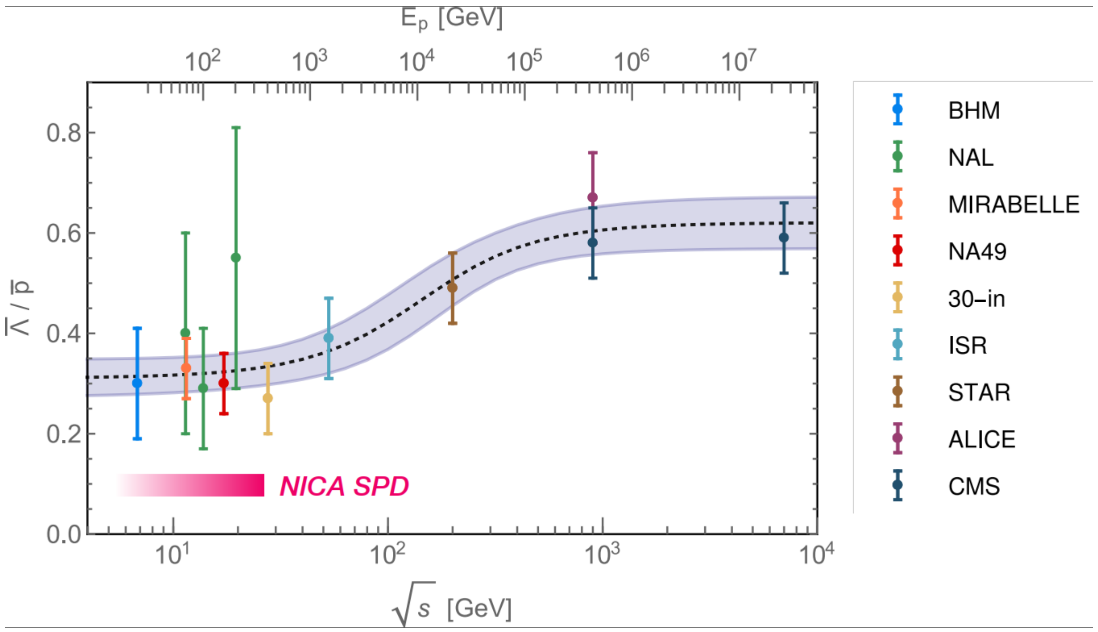
Necessary parameter-space coverage[1] to match AMS-02 precision:

3% within contours

30% outside contours



Accounting for hyperon-induced antiprotons via reconstruction of secondary vertices[2]



$$X_R = \frac{E_p^*}{E_{p\max}^*}$$

Tests of Fundamental Discrete Symmetries at NICA Facility: addendum to the spin physics programme

I. Koop, A. Milstein, N. Nikolaev, A. Popov, S.Salnikov, P. Shatunov and Yu.Shatunov

New approach to spin physics at NICA as a high-intensity source of polarized protons and deuterons

- Test of the Standard Model (SM) via parity violation in single-spin pN and pA scattering: search for the PV asymmetry $< 10^{-7}$
- Beyond SM semistrong CP(T)-violation in double polarized pD scattering: search for T-forbidden vector-tensor asymmetry down to $10^{-\{5-6\}}$
- Principal novelty: in the ring-plane precessing polarization of stored particles and Fourier analysis of oscillating vector and tensor asymmetries

Decomposition of the pd total X-section (k = collision axis)

$$\sigma_{\rm tot} = \sigma_0 + \sigma_{\rm TT}\left[\left(\mathbf{P}^{\rm d}\cdot\mathbf{P}^{\rm p}\right) - \left(\mathbf{P}^{\rm d}\cdot\mathbf{k}\right)\left(\mathbf{P}^{\rm p}\cdot\mathbf{k}\right)\right]$$ PC TT

$$+ \sigma_{\rm LL}\left(\mathbf{P}^{\rm d}\cdot\mathbf{k}\right)\left(\mathbf{P}^{\rm p}\cdot\mathbf{k}\right) + \sigma_{\rm T} T_{mn}k_m k_n$$ LL & PC tensor

$$+ \sigma^{\rm p}_{\rm PV}\left(\mathbf{P}^{\rm p}\cdot\mathbf{k}\right) + \sigma^{\rm d}_{\rm PV}\left(\mathbf{P}^{\rm d}\cdot\mathbf{k}\right)$$ PV single spin at NICA

$$+ \sigma^{\rm T}_{\rm PV}\left(\mathbf{P}^{\rm p}\cdot\mathbf{k}\right) T_{mn}k_m k_n$$ PV tensor

$$+ \sigma_{\rm TVPV}\left(\mathbf{k}\cdot\left[\mathbf{P}^{\rm d}\times\mathbf{P}^{\rm p}\right]\right)$$ TVPV

TVPC $$+ \sigma_{\rm TVPC} k_m T_{mn}\epsilon_{nlr}P^{\rm p}_l k_r \,.$$ (TRIC Proposal in Juelich)

$$k_m T_{mn}\epsilon_{nlr}P^{\rm p}_l k_r = T_{xz}P^{\rm p}_y - T_{yz}P^{\rm p}_x$$

05.10.2020 13

N. Nikolaev, F. Rathman, A. Silenko, Yu. Uzikov, PLB 811 (2020) 135983

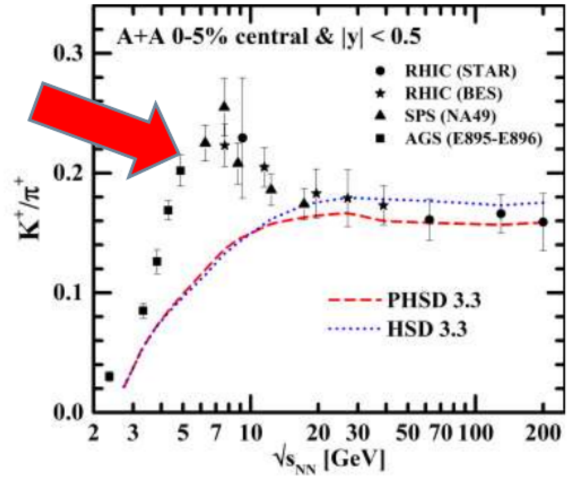
Collisions of light nuclei, Hot baryon matter

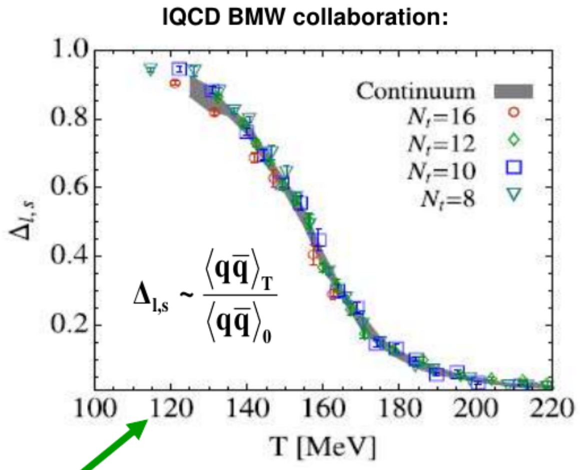
Elena Bratkovskaya
(GSI Darmstadt & Uni. Frankfurt)

‚Flavour chemistry' of HIC: K^+/π^+ ‚horn' – 2015

PHSD: even when considering the creation of a QGP phase, the K^+/π^+ ‚horn' seen experimentally by NA49 and STAR at a bombarding energy ~30 A GeV (FAIR/NICA energies) remained unexplained (2015)!

➔ The origin of the 'horn' is not traced back to deconfinement ?!



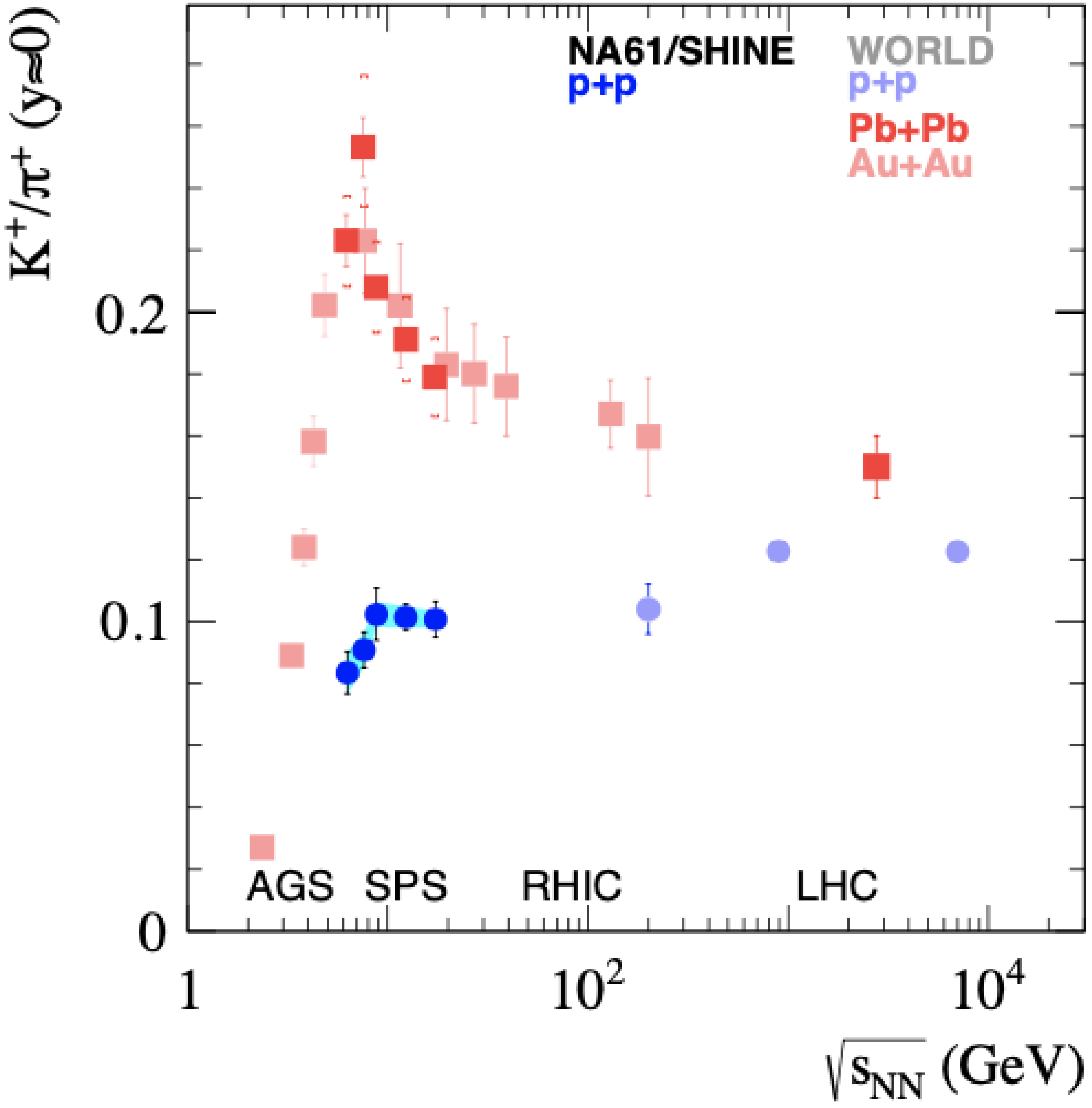


?

Can it be related to chiral symmetry restoration in the hadronic phase?!

$\sqrt{s_{NN}}$ [GeV]

Chiral symmetry restoration leads to the enhancement of strangeness production in string fragmentation in the beginning of HICs in the hadronic phase.
➔The „horn" structure is due to the interplay between CSR and deconfinement (QGP)



NA61/SHINE: pp->$K^+(\pi^+)X$

A.Aduszkiewicz et al. PRC 102 (2020)

The horn in the region of SPD NICA ?

What about pn-channel?

See also CDR of the SPD NICA

TO CONCLUSION

- Which experiment is the most important and unique among above considered suggestions ?

- There is no some "crucial observable" to test the QCD

- Others suggestions for the first stage of the SPD NICA are welcome

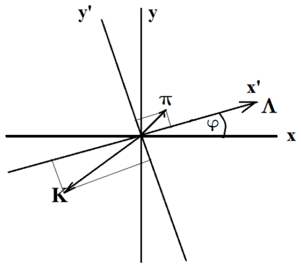
Thank you for your attention!

BUCKUP

Problems of soft PP interactions

A. Galoyan and V. Uzhinsky

New Two-particle P_T correlations



two-particle P_T correlation function can be determined as:

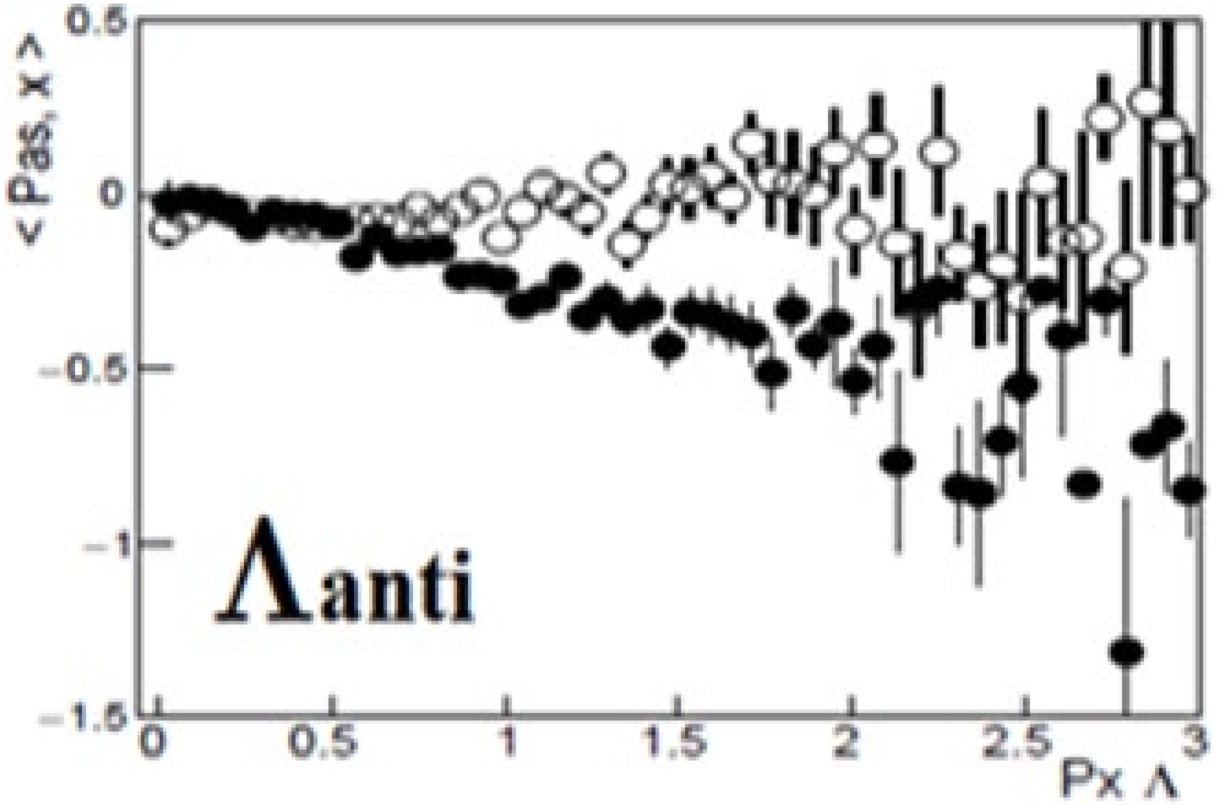
$$C(\vec{P}_T^{tr}, \vec{P}_T^{as}) = \frac{1}{N_{tr}} \frac{d\ N(tr, as)}{d^2 P_T^{tr}\ d^2 P_T^{as}},$$

The function C is a function of 4 independent variables. Though, accounting azimuthal symmetry of interactions of unpolarized particles there must be only 3 independent variables.

We propose to use as the variables the module of transverse momentum of the trigger particle ($|\vec{P}_T^{tr}|$), and 2 projections of the vector $\vec{P}_T^{as}$ on the direction of the vector $\vec{P}_T^{tr}$, and on the direction perpendicular to $\vec{P}_T^{tr}$ In Fig. we choose Λ as a trigger particle, and K-meson or π-meson as associated particles.

$$P_{T,L}^{as} = \vec{P}_T^{as} \cdot \vec{P}_T^{tr} / |\vec{P}_T^{tr}|,$$

$$P_{T,T}^{as} = |\vec{P}_T^{as} \otimes \vec{P}_T^{tr}| / |\vec{P}_T^{tr}|$$

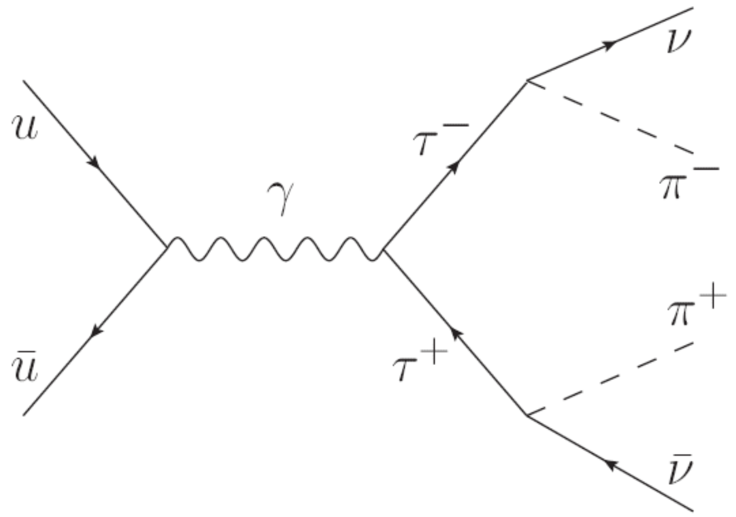


Averaged projections of associated particle momentum (Pass,x) on trigger particle momentum (Px Λ) in pp interactions at Ecms=10 GeV. Open points – Pythia 6.4 calculations. Closed ones are FTF calculations.

There is a big difference between model predictions!

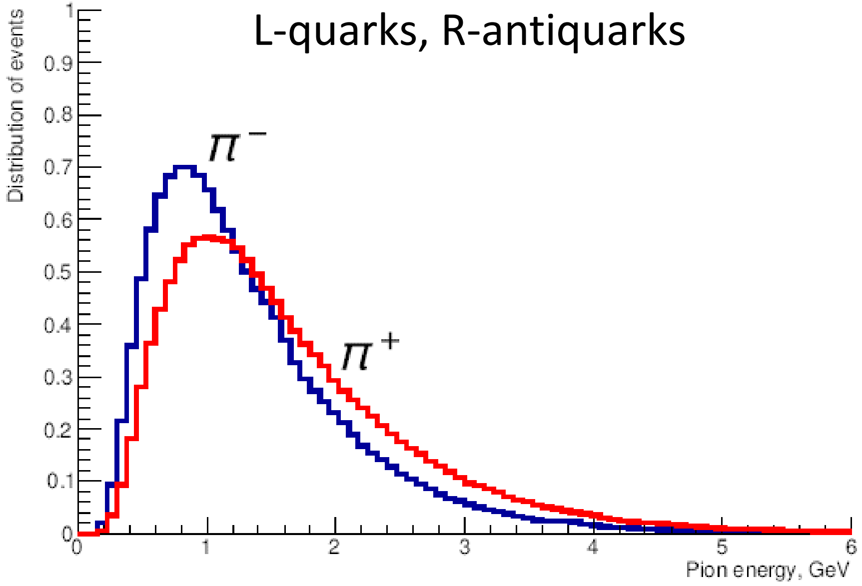
PDF and polarized tau-leptons production

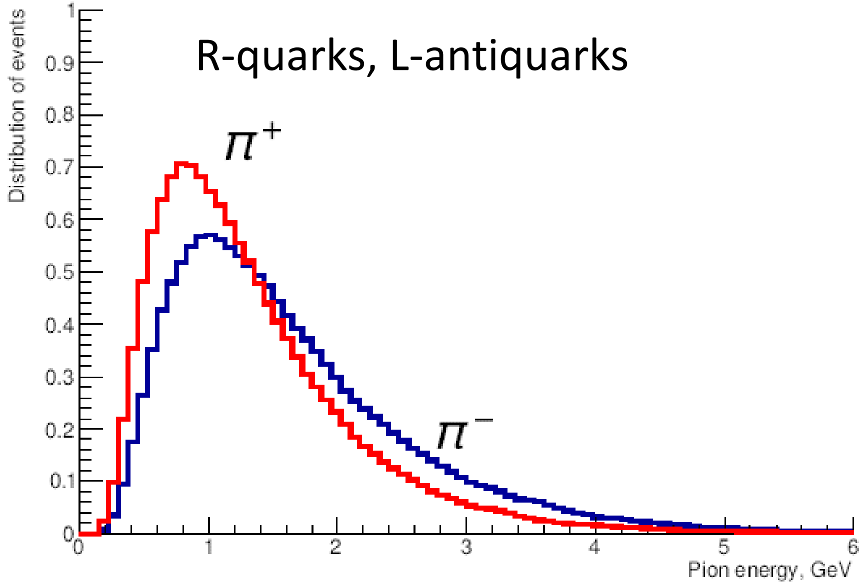
A. Aleshko, E. Boos, V. Bunichev



Energy of pi-meson depends on polarization of tau-lepton

$$\sqrt{s} = 24GeV^2$$





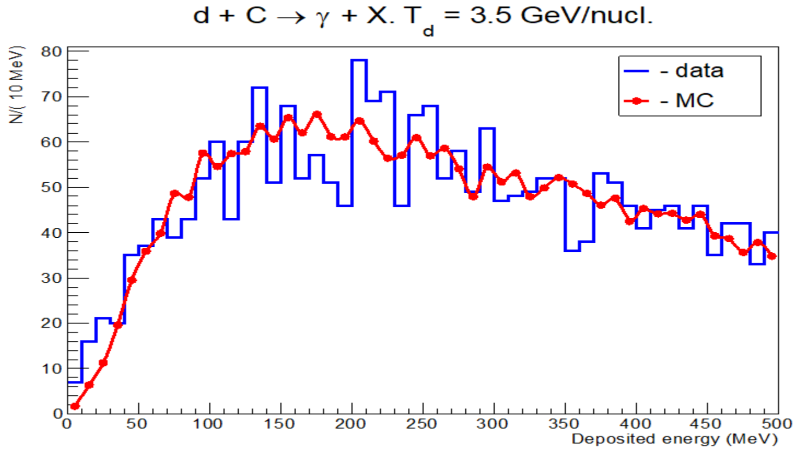
EXOTICS

Soft Photon (SP) study yield in proton and light nuclei interactions at SPD-NICA setup

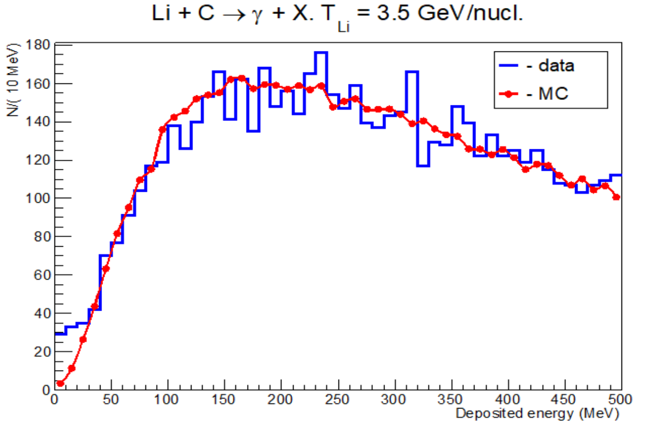
E.Kokoulina, V. Nikitin

SP have energy smaller than 50 MeV. The main mechanism of their formation is Compton scattering of soft gluons on valence quarks at the final stage of hadronization with the photon radiation: $q + g \rightarrow \gamma + q$.

Over 30 years several experiments have confirmed the increased yield of SP compared to theoretical calculations, but there is still no comprehensive understanding and explanation of this phenomenon.



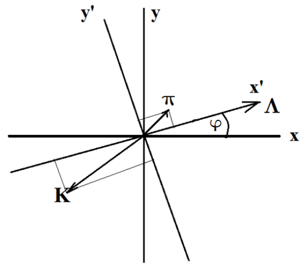
50th and 51st Nuclotron's runs.



Problems of soft PP interactions

A. Galoyan and V. Uzhinsky

New Two-particle P_T correlations



two-particle P_T correlation function can be determined as:

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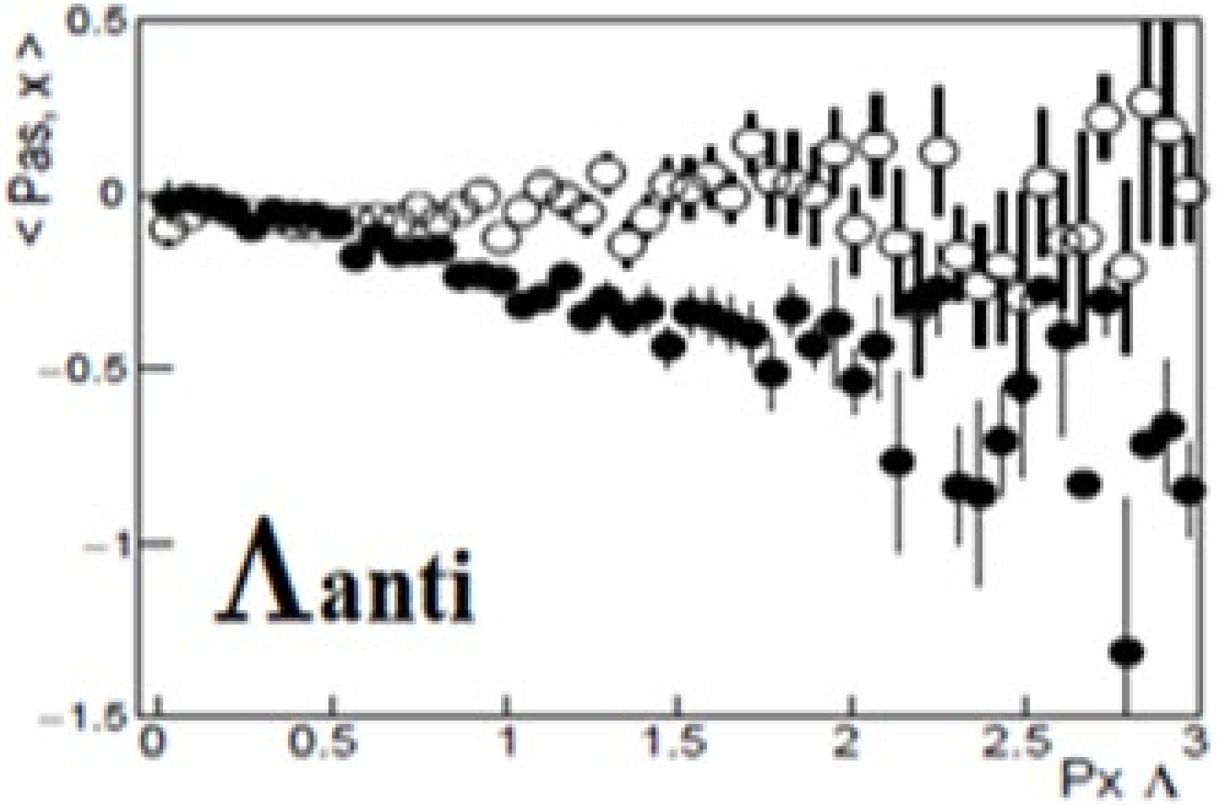

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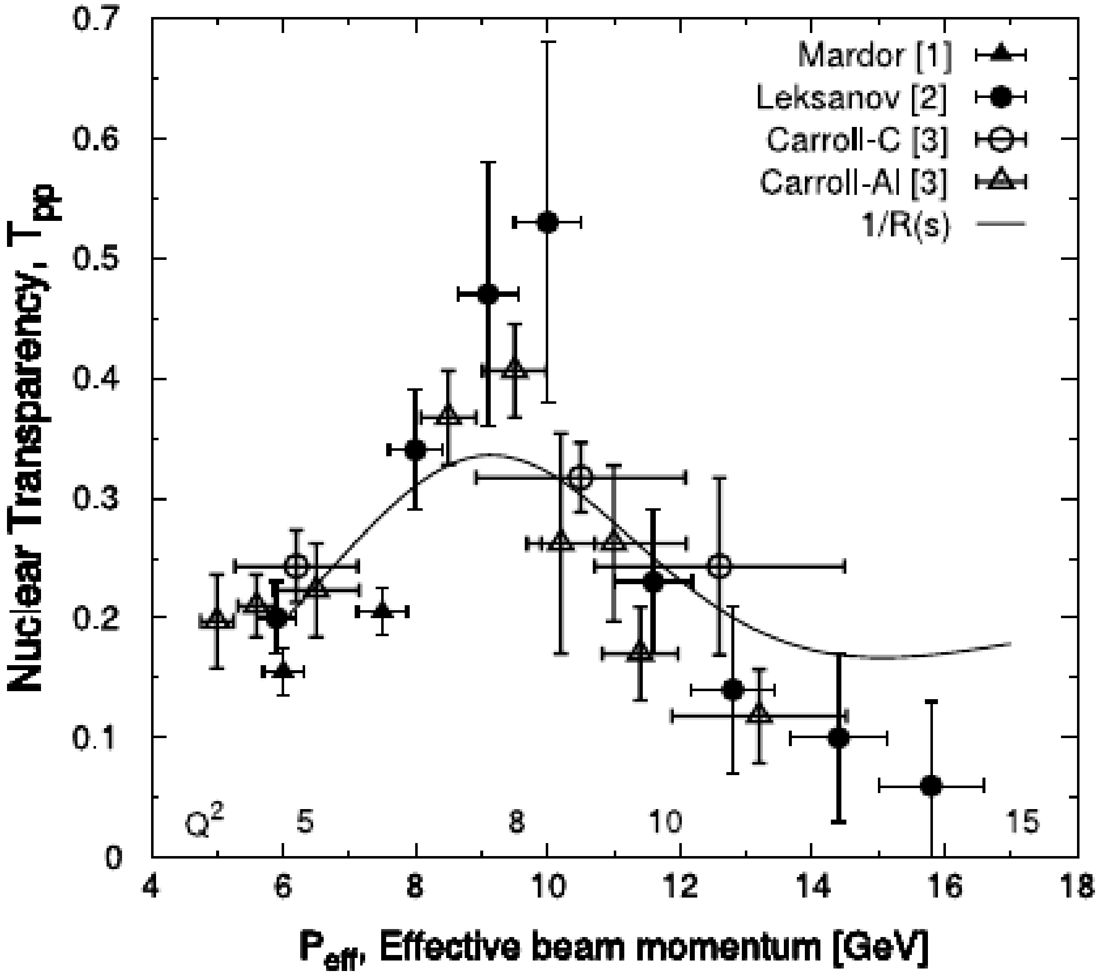
There is a big difference between model predictions!

PUZZLE

CT in play-> p+p+(A-1) at BNL

D. Dutta et al. / Progress in Particle and Nuclear Physics 69 (2013) 1–27



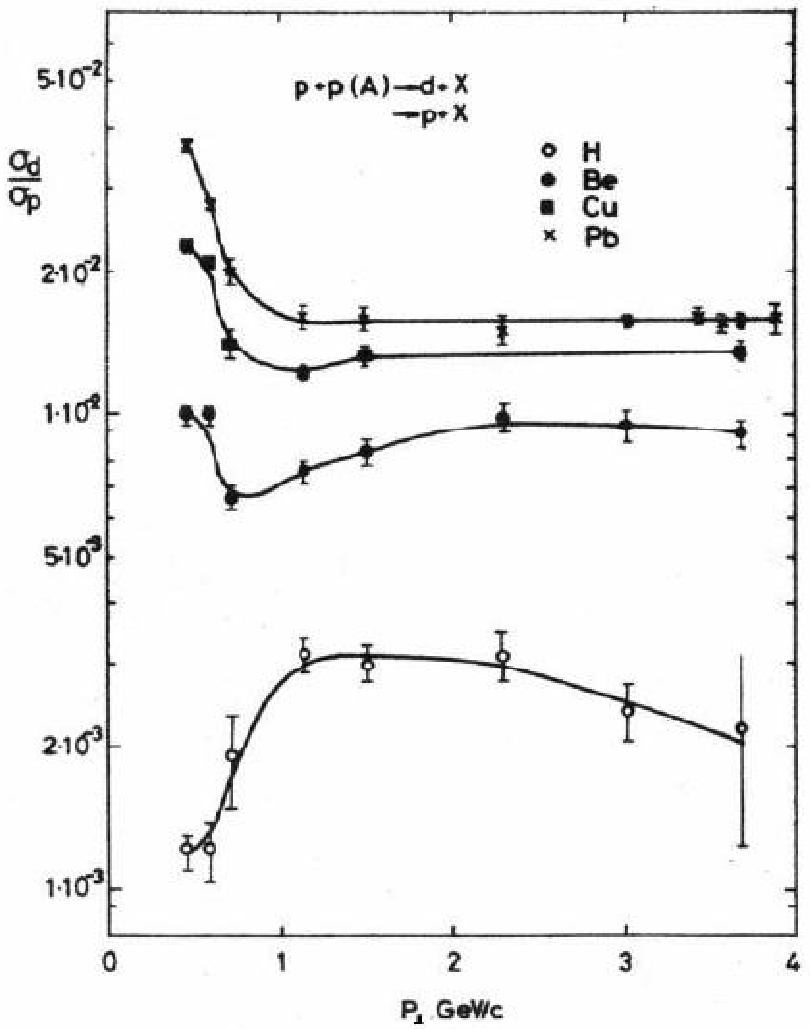
A possible explanation:
charm quark resonances
at the charm threshold or
exotic multi-quark states
(see above large angle pp-
scattering)
S. Brodsky , G. F. de
Teramond, PRL (1988)
However, the region is too
broad for resonances

$$4.9GeV \le \sqrt{s_{NN}} \le 5.5GeV$$

(Dutta et al 2013)

Ratio d/p

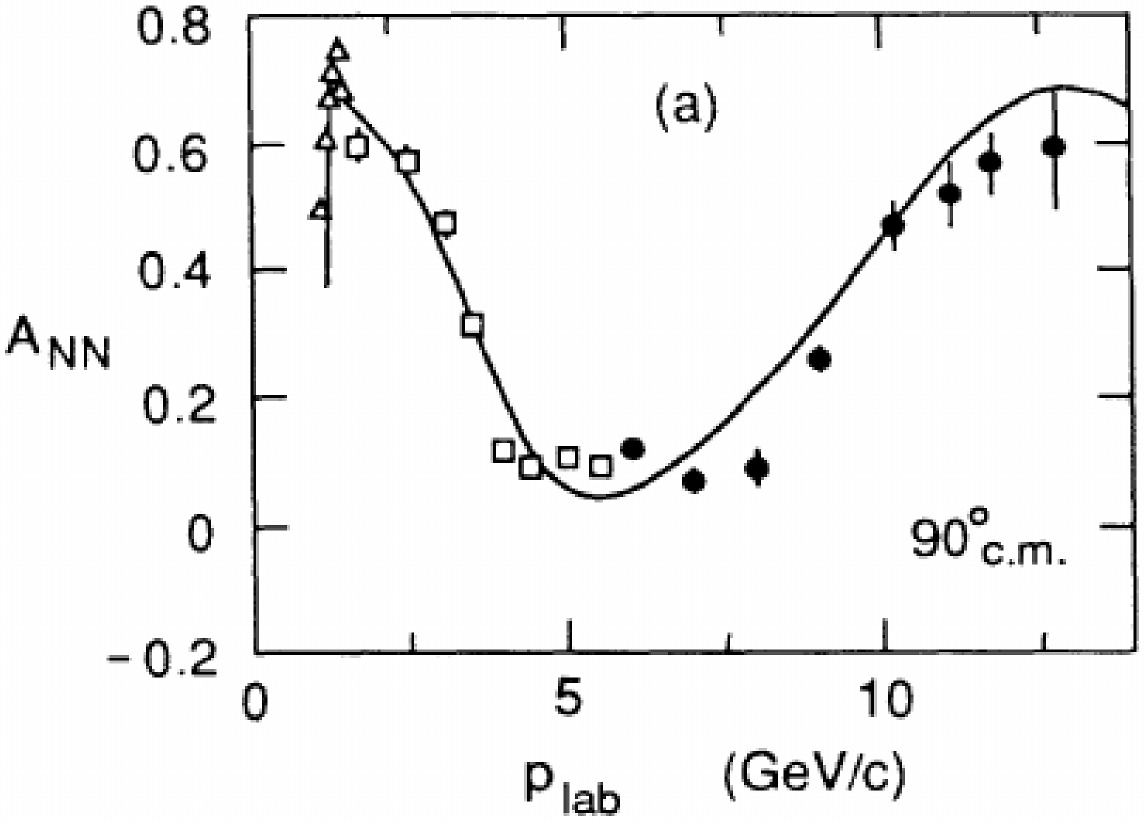
ФОДС	В.В.Абрамов и др., ЯФ 45(5) (1987), 845–851

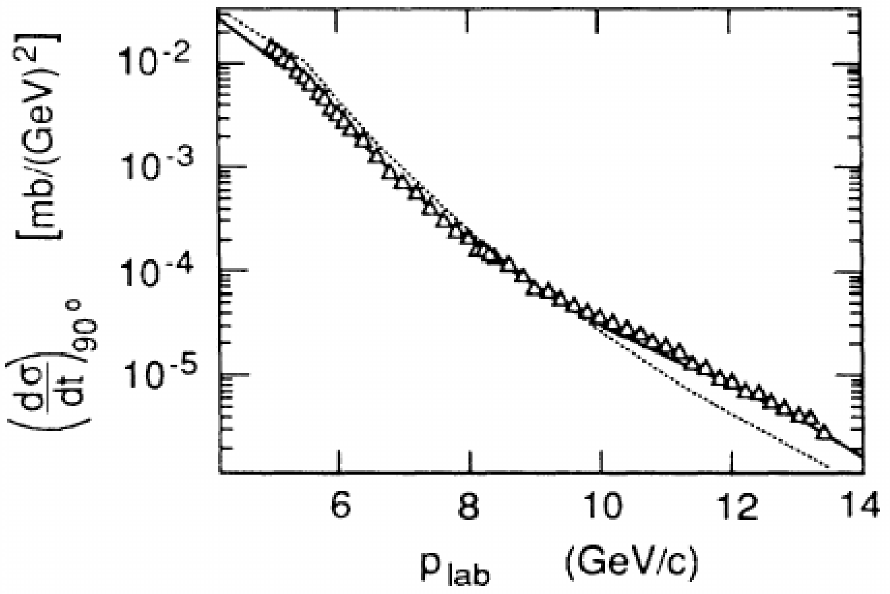


VOLUME 60, NUMBER 19 PHYSICAL REVIEW LETTERS 9 MAY 1988

Spin Correlations, QCD Color Transparency, and Heavy-Quark Thresholds in Proton-Proton Scattering

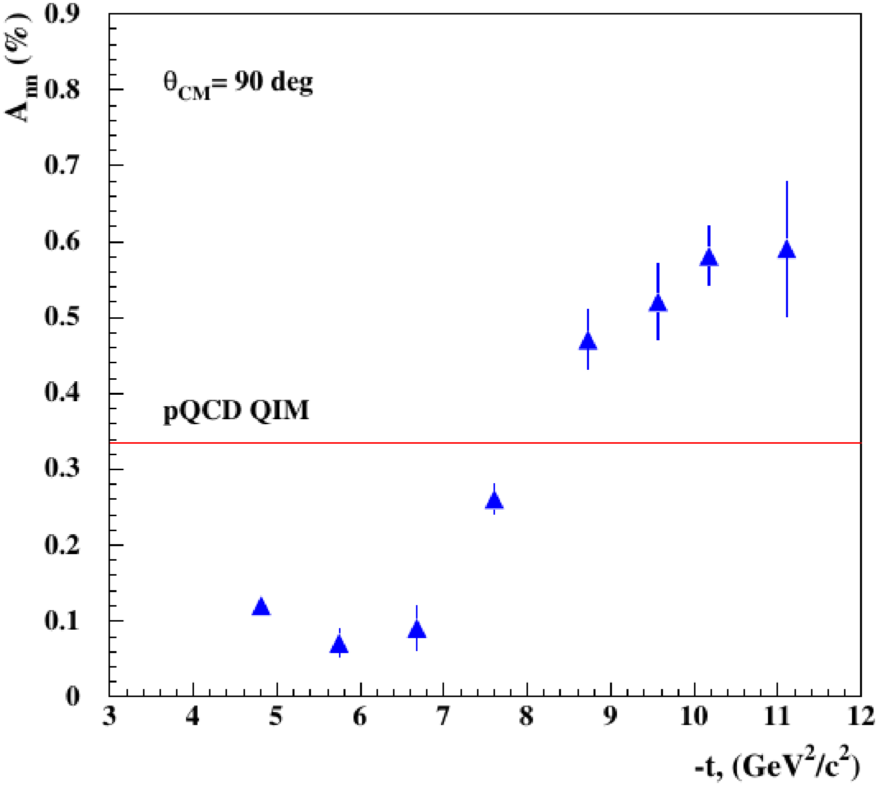
Stanley J. Brodsky and Guy F. de Teramond
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

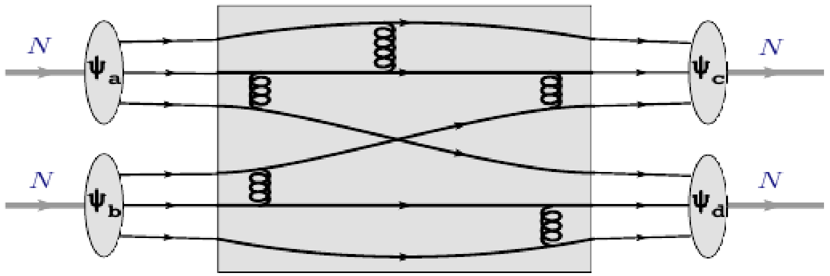




1. Prediction (solid curve) for $d\sigma/dt$ compared with ı of Akerlof *et al.* (Ref. 16). The dotted line is the und PQCD prediction.

$$A_{NN} = \frac{d\sigma(\uparrow\uparrow) - d\sigma(\uparrow\downarrow)}{d\sigma(\uparrow\uparrow) + d\sigma(\uparrow\downarrow)}$$





pQCD QIM

M.Sargsian (2014)

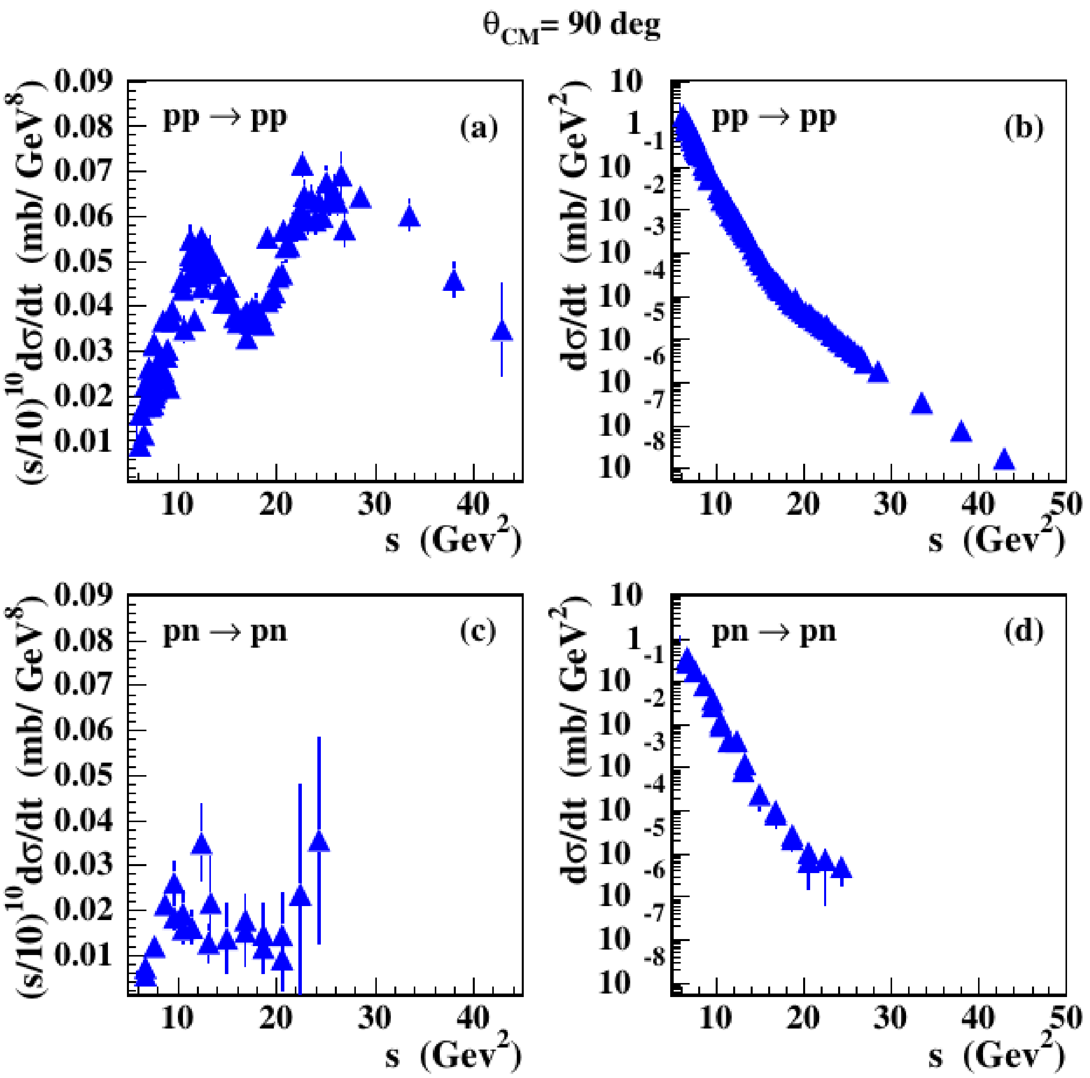


Figure 1. The invariant energy dependence of elastic *pp* and *pn* differential cross sections unweighted (b) (d) and weighted by s^{10} factor (a), (c). The experimental data are from Ref. [50, 51, 52, 53, 54].

V.Komarov et a.l PLB 553 (2003);
J.Haidenbauer, Yu.N. U. PLB 562 (2003)