Large-p_T hadron correlations in pp-collisions at NICA energies

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Outline

- Types of multiquark correlations and interactions
- ULYSSES MC generator with diquarks
- Summary

Introduction

Processes involving multiquark degrees of freedom can shed light on various aspects from multiquark fluctons, diquarks, multiparton scattering
to exotic resonance production
and fulfil a broad and rich physics program at **SPD** experiment.

Multiquark phenomena may be separated by four cases:

- Multiquark fluctons in nuclei
- Few-quark correlations (diquarks)
- Multi-parton interaction [MPI] (multiquark scattering)
- Multiquark exotic states production

Fluctons in nuclei

Cumulative processes off nuclei ➟ Multiquark fluctons (Shot-range correlations)
Nuclear form factors

A.V. Efremov (1976), V.K. Lukyanov, A.I.Titov, V.V. Burov (1977)
L.L. Frankfurt, M.I. Strikman (1976)

Fermi-motion cannot explain high-momentum nucleons

Few-quark correlations: diquarks

Diquark is a two-quark correlation in baryons.

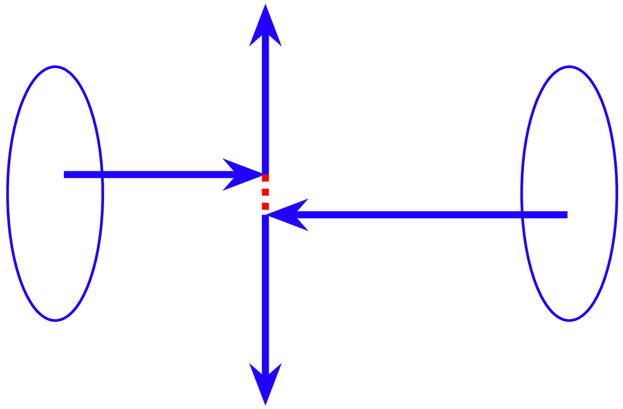
Such type of correlation does play an important role in large-p_T baryon production.

Being a higher-twist, the diquark contribution can describe the strong scaling violation in deep inelastic scattering off nucleons and in large-p_T baryon production in hard nucleon collisions at **SPD** energies

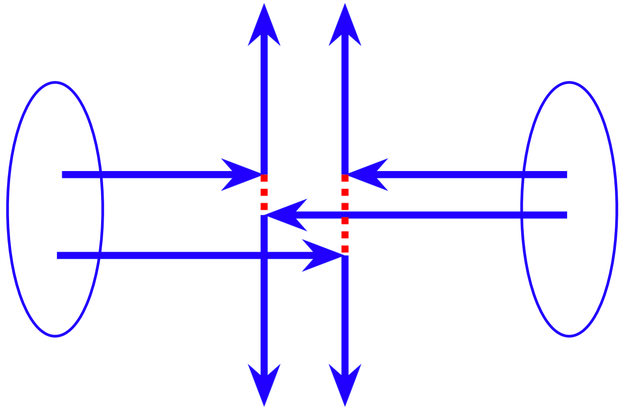
The framework of a diquark model of nuclei is implementing in **ULYSSES** (PYTHIA 8 based) MC event generator.

Multiparton scattering

Single parton scattering



Double parton scattering

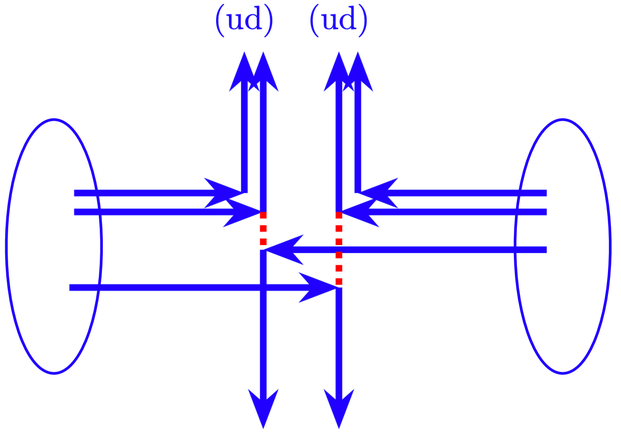


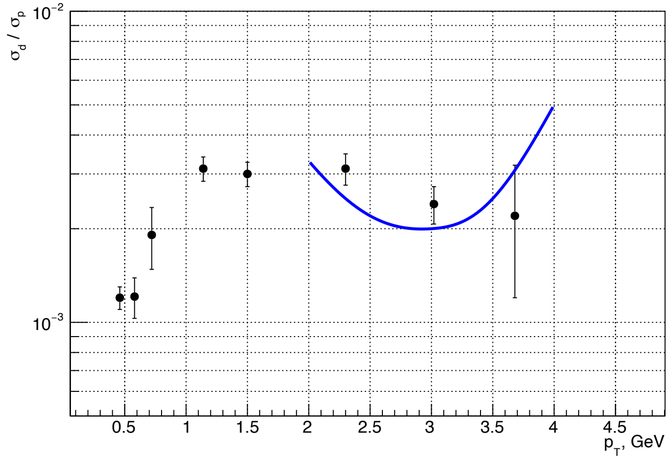
Multiquark exotic state production

Production of multiquark systems with possible diquark structure on large angles can be enhanced due to double diquark–quark scattering. Inclusive and two-particle correlation studies with production of various particles and nuclei should help establishing two production mechanism stages: multiparton scattering and fusion process.

This two stage mechanism could be a source for production deuterons and exotic multiquark resonances: H-dihyperons, pentaquark, tetraquarks

Therefore, **SPD** experiment provides an uniqe opportunity to search such multiquark states at unexplored kinematic domain.





A.V. Efremov, V.T. Kim (1987)

d/p - ratio data (pp 70 GeV): FODS, V.V. Abramov et all (1987)

SPD First Stage … V.V. Abramov et al. (2021)

ULYSSES MC event generator

Done

- ✓ Implementation of scalar (ud) diquark in hard hadronic processes:
  - ✓ diquark structure function
  - ✓ evolution of diquark structure function

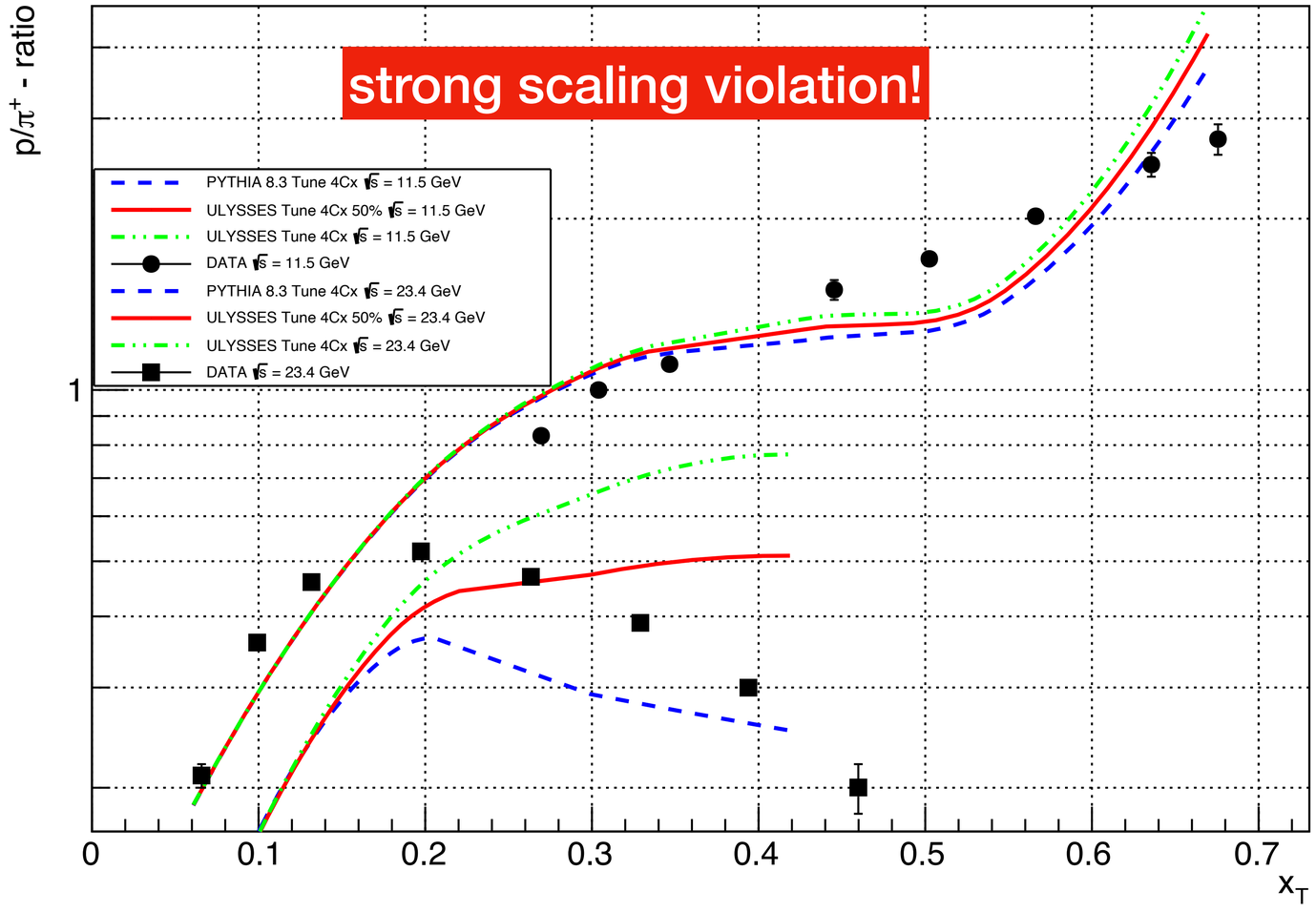
In Progress

- Implementation of vector (uu) diquark in hard hadronic processes
- Multiparton interactions with diquarks

Proton production in hard pp collisions

SPD First Stage … V.V. Abramov et al. (2021)

$$x_T = 2p_T/\sqrt{s}$$



Diquark model can explain strong scaling violation

p/π^+-ratio of inclusive invariant cross sections at $\theta_{\text{cms}} = 90^0$ in pp-collisions confronted with the data

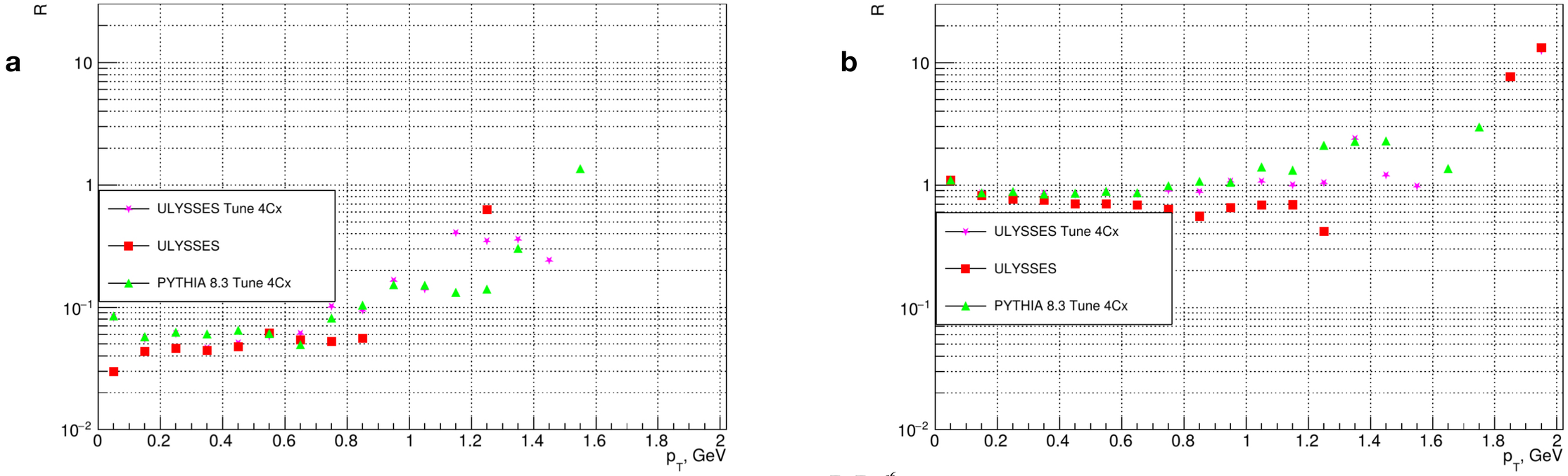
IHEP, Protvino (•) at $\sqrt{s} = 11.5$ GeV
FODS, V.V. Abramov et al. (1985)

FNAL, Batavia (■) at $\sqrt{s} = 23.4$ GeV
D.Antreasyan et al. (1979)

The predictions from MC event generator ULYSSES with incorporated diquark subprocesses: the solid red line corresponds diquark state probability in proton equals *0.5*, the dash–dotted green line—*1.0*. Prediction by the *standard PYTHIA8.3 Tune 4Cx* without diquark subprocesses is shown by the blue dashed line.

Two-proton correlation

SPD First Stage … V.V. Abramov et al. (2021)



$$R_{12} = \sigma_{in} \cdot \frac{\dfrac{E_1\, E_2\, d^6\sigma_{12}}{d^3p_1\, d^3p_2}}{\dfrac{E_1\, d^3\sigma_1}{d^3p_1} \cdot \dfrac{E_2\, d^3\sigma_2}{d^3p_2}}$$

Two-proton correlation function at $\theta_{\text{cms}} = 90^0$ in pp-collisions at $\sqrt{s} = 23.4$ GeV as a function of p_T ($\simeq p_{T_1} \simeq p_{T_2}$) for two regions of azimuthal angle difference: (a) for back-to-back region ($\Delta\varphi = |\varphi_1 - \varphi_2| \approx \pi$) and (b) out of it ($\Delta\varphi \neq \pi$). The preliminary predictions from MC event generator **ULYSSES** with incorporated diquark subprocesses in different tunes (red squares and magenta stars) and PYTHIA 8.3 Tune 4Cx (green triangles) without diquark subprocesses.

Conclusion

- Multiquark correlations in the collisions of particles and nuclei at **NICA** energies play an important role in understanding of QCD

- **SPD** can carry out investigations of the novel production mechanisms as double quark–diquark scattering and the other multiparton scattering subprocesses, which would lead to enhanced production of exotic multiquark resonance states and light nuclei