Candidate: Tetiana Yushkevych

Title of the Thesis: Perturbative and Non-Perturbative Aspects of Hadronic Physics

Supervisors: Prof. Mariaelena Boglione with Prof. Ihor Sharf from Odesa National Polytechnic University

Name of the reviewer: Dr. Markus Diefenthaler

Reviewer's institution: Jefferson Lab in Newport News, Virginia, United States of America.

Please rate the following points:

	Insufficient	Sufficient	Good	Excellent
Overall scientific merit (originality, relevance, completeness)				X
Introduction and bibliography (sufficient information provided by the introduction, appropriate cited references)			X	
Methodology (clearly described methods, adequate and exhaustive data analysis (if applicable)				X
Results (convincing and clearly presented results, adequate number and quality of tables and figures)				X

Overall evaluation (please check one)

- [x] **The candidate can be admitted to the final examination**
- [ ] **The candidate can be admitted to the final examination but the thesis requires minor revision; further evaluation by the reviewer is not required**
- [ ] **To be admitted to the final examination the thesis requires extensive revision; the revised version must be provided within 6 months and must be re-evaluated by the reviewer**

Specific comments and suggestions [mandatory]

Please see next side.

The thesis by Tetiana Yushkevych demonstrates an impressive combination of theoretical development and phenomenological application in the context of Quantum Chromodynamics. The candidate has played a central role in developing a dynamical model for elastic proton–proton and proton–antiproton scattering using the multiparticle field framework.

Her original application of the Laplace method to compute loop diagrams within this model represents a significant advance, allowing for the treatment of non-perturbative spin-dependent effects with analytical and numerical rigor. Understanding spin effects is key to understanding hadron structure, and this thesis provides valuable insight into how spin dynamics contribute to observed features in elastic scattering, such as the non-monotonic behavior of the differential cross section.

Equally notable is the candidate’s work on semi-inclusive deep inelastic scattering (SIDIS), where she developed an affinity-based methodology to classify kinematic regions in a more precise and data-driven manner. The transition from bin-averaged to event-by-event analysis marks a clear conceptual and technical improvement, enhancing the interpretation of TMDs and collinear factorization regimes.

These contributions address one of the key questions in the extraction of information about TMDs from experimental measurements—namely, identifying the regions where collinear and TMD factorization theorems can be reliably applied. Advancing our understanding of TMD measurements and the applicability of TMD factorization theorems is also relevant for testing and deepening our understanding of quantum field theories, which are core to explaining the structure of matter in the visible universe. These contributions are highly relevant for current and future experimental programs at Jefferson Lab and the planned Electron-Ion Collider. The improved understanding of kinematic transitions and non-perturbative effects directly informs the analysis of SIDIS data and the extraction of TMDs. Her methods provide concrete tools for guiding experimental measurements and validating factorization assumptions.

The thesis is well-structured, clearly written, and supported by detailed calculations and appropriately cited literature. The combination of theoretical innovation and phenomenological relevance, coupled with clear personal contributions throughout, makes this an excellent doctoral thesis. I strongly recommend the candidate for admission to the final examination without the need for revision.

Date and Signature

Markus Diefenthaler

Dr. Markus Diefenthaler
Friday, August 29, 2025

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