



## Lessons from the TMD Collaboration

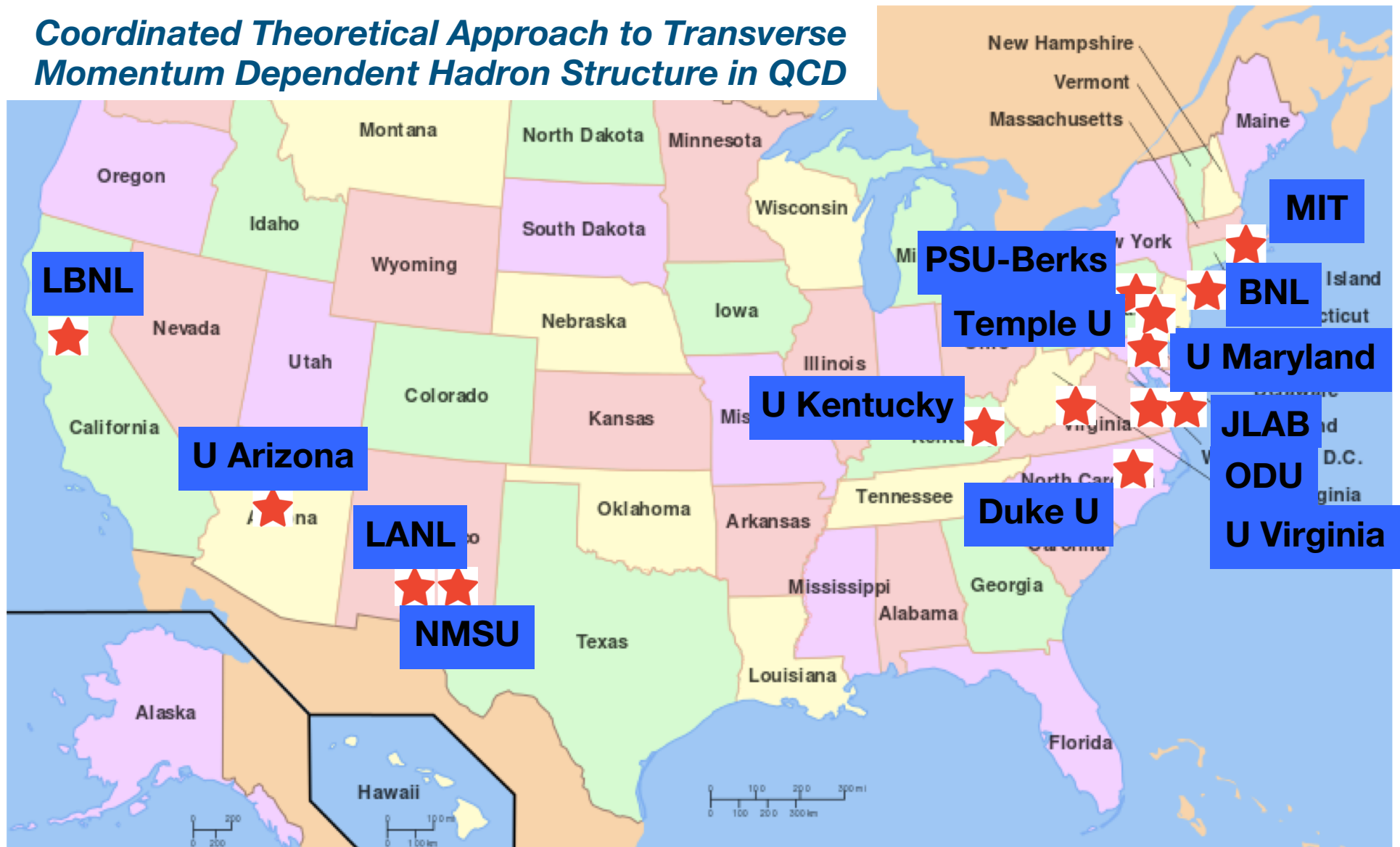
- a) The BEST/TMD proposals were successful
- b) Why the collaboration worked - organization, activities
- c) Pitfalls to avoid, or what could have been done differently or better
- d) Importance or not of foreign collaborators / experimentalists as affiliates of the proposal; their impact on its activities
- e) Advice on what kind of problems or effort in our proposed topic(s) that you think may be relevant *(request from Raju ...)*

**Jianwei Qiu**

**Theory Center, Jefferson Lab**

# The TMD Collaboration

*Coordinated Theoretical Approach to Transverse Momentum Dependent Hadron Structure in QCD*



**10 States, 14 Institutions**

# The Team

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- **Co-Spokespersons:**

W. Detmold (MIT), J.-W. Qiu (JLab)

- **Institutions & Members: 21 Members + Postdocs + Students + Affiliate Members**

Brookhaven National Lab (R. Venugopalan)

Duke University (T. Mehen)

Jefferson Lab (J.-W. Qiu)

Lawrence Berkeley National Lab (F. Yuan)

Los Alamos National Lab (C. Lee, I. Vitev)

Massachusetts Institute of Technology (W. Detmold, J. Negele, I.W. Stewart)

New Mexico State University (M. Burkardt, M. Engelhardt, M. Schlegel)

Old Dominion University (T. Rogers, joint with JLab)

Penn State University at Berks (L. Gamberg, A. Prokudin, bridged with JLab)

Temple University (M. Constantinou, A. Metz)

University of Arizona (S. Fleming)

University of Kentucky (K.-F. Liu)

University of Maryland (X.-D. Ji)

University of Virginia (S. Liuti)

***4 National Labs, 10 Universities***

# The Team

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- **Bridged Faculty:**

M. Constantinou (Fall 2016, Temple U),  
M. Schlegel (Spring 2018, NMSU)

- **Postdocs:**

D. Pitonyak (2016-18, PSU-Berks/ODU → Assist. Prof. Lebanon Valley College),  
Y. Yang (2016-17, Kentucky U → Staff, ITP, Chinese Academy of Science),  
Y. Zhao (2016-19, MIT, 2019-2021, BNL) → Staff, Argonne Nat'l Lab  
J. Liang (2017-2018, Kentucky), L. Dai (2018-2020, Duke U),  
N. Sato (2018-19, ODU) → Nathan Isgur Fellow, Staff, JLab,  
A. Tarasov (2018-19, BNL), Z. Liu (2018-2020, LANL), ... ..

- **Students:**

M. Albright, S. Dolan, Z. Scalyer (PSU-Berks), K. Lee (Stony Brook),  
Ou Labun (Arizona), A. Rajan (UVa → PD, BNL), ...

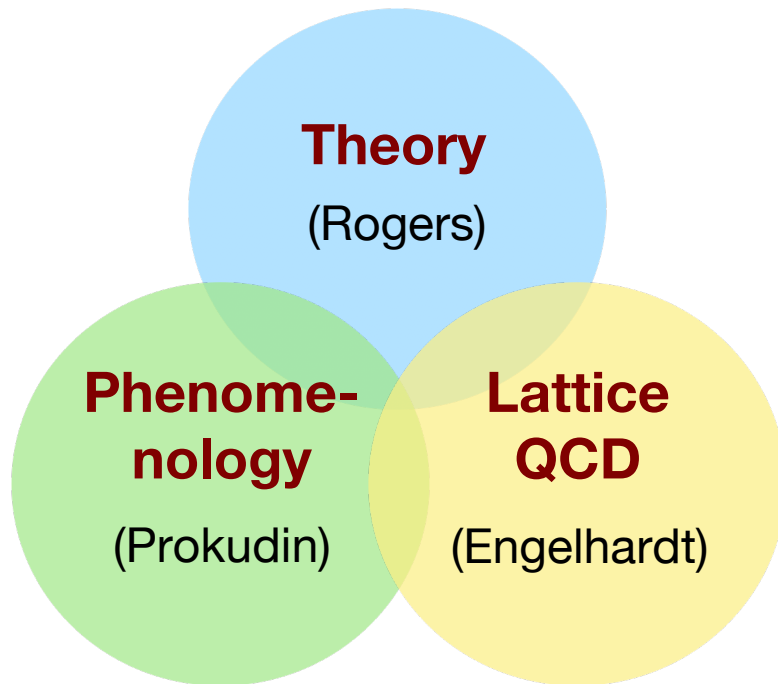
- **Affiliate members – network:**

J.-W. Chen (NTU, Taiwan), J.C. Collins (PSU), Z.-B. Kang (UCLA),  
L. Jin (Connecticut), D. Lin (NSTU, Taiwan), H.-W. Lin (MSU), A. Schaefer (Regensburg),  
P. Schweitzer (Connecticut), P. Shanahan (MIT), G. Sterman (Stony Brook),  
H.-X. Zhu (Zhejiang U), D. Neill (Feynman Fellow, LANL), M. Ebert (MIT),  
Y.-S. Lin (SJTU, China), Y. Makris (LANL), M. Sievert (LANL), M. Wagman (MIT),  
S. Yoshida (LANL), J.-H. Zhang (Regensburg), Y. Hatta (BNL), Y. Kovchegov (OSU), ...



# The Method, Service, Productivity

## Coherent three-pronged approach:



### Theory

#### – Strengthen the theoretical foundation of TMD physics;

- Scrutinize the definition,
- Broaden our knowledge on the role and impact of TMDs
- Devise new ways to access them
  - connection to facilities, JLab, RHIC, the LHC, EIC

### Phenomenology

#### – Extract TMD knowledge from experimental data

- Develop fast software to do global fit of TMDs
- Produce extensive TMDs from global fitting data
- Make them available to the community

### Lattice QCD

#### – Pursue non-perturbative calculations of TMDs

- Establish LQCD capability to study partonic structure
- Understand nonperturbative input to TMD evolution
- Explore the nature of parton orbital angular momentum

## Service to the community and productivity:

Provide compelling research, training and career opportunities for young nuclear theorists

- including the undergraduate and graduate students, postdocs, and junior faculty
- TMD summer school, TMD handbook, ...

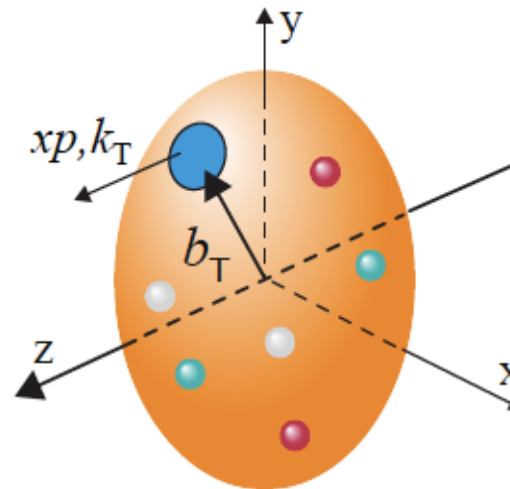
# Overarching TMD Questions

What are the 2D confined transverse motion of quarks and gluons inside a colliding proton?

How to identify universal proton structure properties from measured  $k_T$ -dependence?

How does the confined motion change along with probing  $x$ ,  $Q^2$ ?

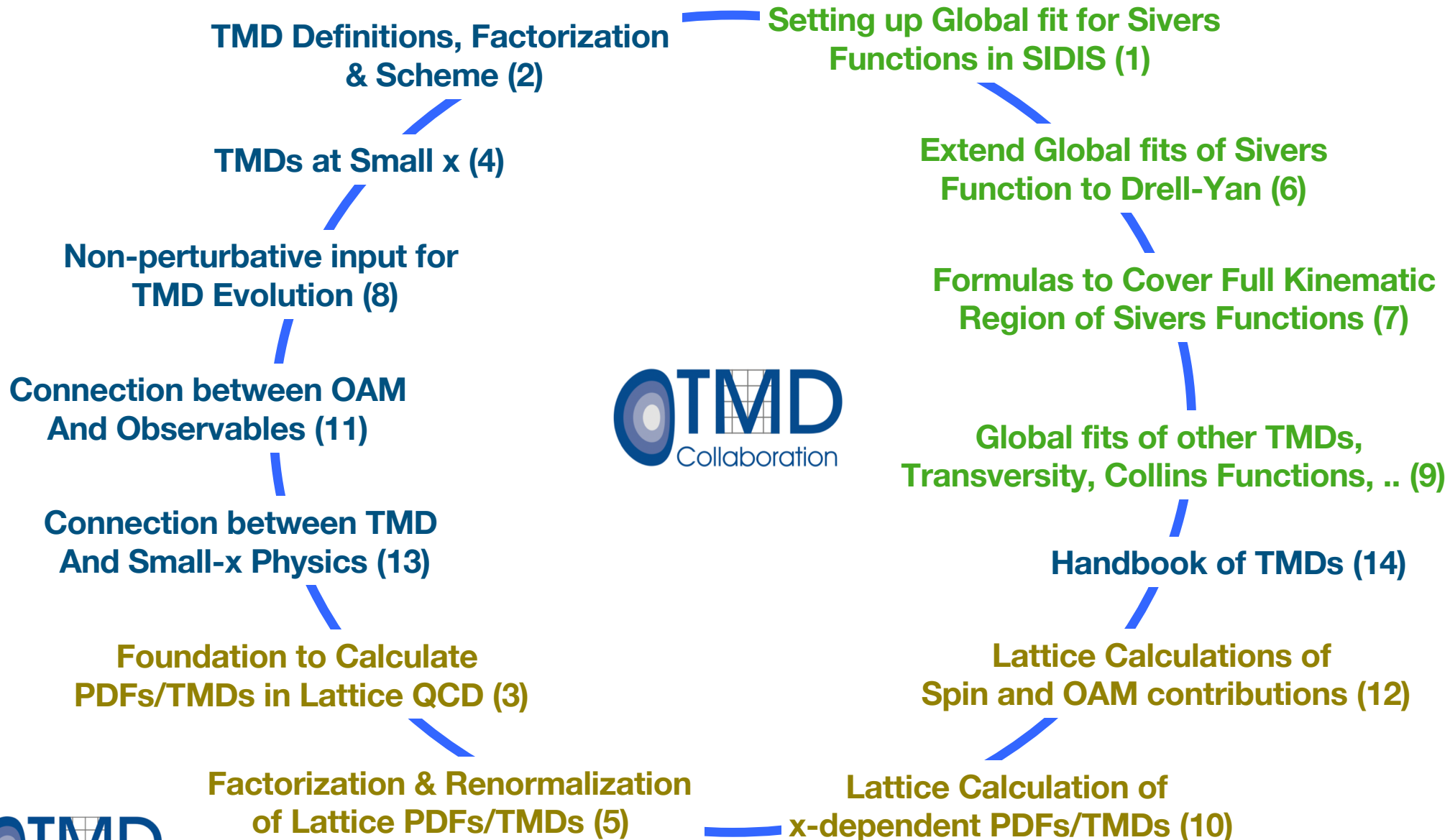
Can we extract QCD color force responsible for the confined motion?



How is the motion correlated with macroscopic proton properties, as well as microscopic parton properties, such as the spin?

# Proposed Milestones

- A multi-prong, coherent and integrated effort:



# The TMD Activities

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- **Annual collaboration meetings:**

- Organized at different collaborative institutions
- Awareness of the TMD activities
- Review progresses, milestone status, and the preparation of progress reports
- Presentations of postdocs and students, strengthen the network
- Collaboration business sessions

- **Topical and focused workshops:**

- Solve one problem at a time
- Connecting to experimentalists
- Involvement of domestic and foreign affiliated members

- **Collaboration visits:**

- Postdocs and students to travel between collaboration institutions
- Advantage and strength of the collaborative efforts

- **Summer/Winter schools, handbook, ... :**

- Bring career opportunities and training to young nuclear theorists and the community

# Management, Coherence, Priority

## Management – three-level approach:

- 2 Co-Spokespersons + 3 working group leaders
- 2 Co-Spokespersons + appointed committees
- 21 Members of the collaboration

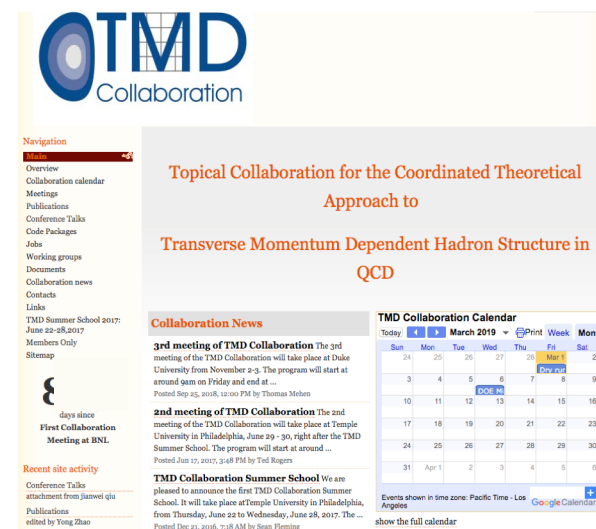
## Communication:

TMD WIKI page: <https://sites.google.com/a/lbl.gov/tmdwiki/>

## Budget priority:

- People (2 bridged, 12 postdocs, 8 graduate students, + 3 undergraduates) – leveraged!
- Collaboration – collaborative visit, collaboration meeting, focused workshops
- Training – summer/winter schools (2017, 2022)

TMD Collaboration	Year 1	Year 2	Year 3	Year 4	Year 5
DOE Award	\$440,000	\$440,000	\$450,000	\$460,000	\$470,000
People - Subcontracts	\$329,000	\$359,785	\$364,093	\$375,593	\$337,808
Collaborative Activities + BNL Burdens	\$111,000	\$80,215	\$85,907	\$84,407	\$132,192



## People + Collaborative Activities



# Service to the Community

## TMD Summer School – June 22 – 28, 2017





# Service to the Community

- **TMD Handbook:**
  - **Fast growth of TMD community**  
– wide range of approaches to TMD physics
  - **Need to unify** the language and terminologies, summarize technologies for TMDs
  - **To survey** the state of experimental data for TMDs, and future opportunities
  - **Comprehensive resource** for students and young postdocs entering the field

## TMD Handbook

A modern introduction to the physics of  
Transverse Momentum Dependent distributions



Renaud Boussarie  
Matthias Burkardt  
Martha Constantinou  
William Detmold  
Markus Ebert  
Michael Engelhardt  
Sean Fleming  
Leonard Gamberg  
Xiangdong Ji  
Zhong-Bo Kang  
Christopher Lee  
Keh-Fei Liu  
Simonetta Liuti  
Thomas Mehen  
Andreas Metz  
John Negele  
Daniel Pitonyak  
Alexei Prokudin  
Jian-Wei Qiu  
Abha Rajan  
Marc Schlegel  
Phiala Shanahan  
Peter Schweitzer  
Iain W. Stewart  
Andrey Tarasov  
Raju Venugopalan  
Ivan Vitev  
Feng Yuan  
Yong Zhao

# Summary

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- **An organized, coherent and interactive scientific collaboration/network**
  - Focusing on QCD and hadron physics, in particular, the physics of TMDs
  - Pulling together expertise in theory, phenomenology, and lattice QCD
  - Forming a unique multi-institution and three-pronged scientific effort
  - Enabling a paradigm shift in our approach taking on projects impossible by single PI
- **Help to strengthen the TMD effort in the U.S.**
  - Two bridged faculty positions were created for QCD and hadron structure
  - Supported 12 postdocs + 8 graduate + 3 undergraduate students
- **Impact on physics programs at JLab, RHIC, future EIC, ...**
  - Achieve all proposed milestones
- **Service to the NP community by training young researchers**
  - Organize summer/winter school, training students, ...
  - Provide theory support to experimental programs
  - Produce the TMD handbook – very important to the community

**Thanks!**