New initiatives for Nuclear Tomography

Nobuo Sato

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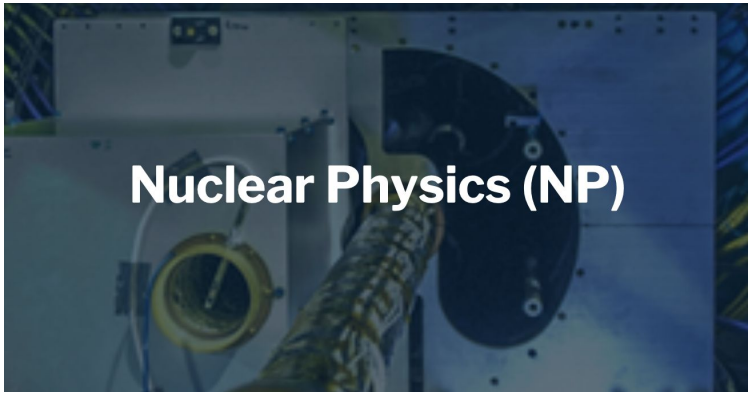
Towards improved hadron femtography with hard exclusive reactions 2023

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science



Topical Collaboration Projects (2022)

1. 3D quark-gluon structure of hadrons: mass, spin, and tomography
2. Heavy-Flavor Theory (HEFTY) for QCD Matter
3. Saturated Glue Topical Collaboration
4. Nuclear Theory for New Physics
5. Coordinated Theoretical Approach for Exotic Hadron Spectroscopy

NP/ASCR SciDAC projects (2022)

1. Femtoscale Imaging of Nuclei using Exascale Platforms
2. Fundamental nuclear physics at the exascale and beyond
3. Nuclear Computational Low Energy Initiative (NUCLEI)

“3D quark-gluon structure of hadrons: mass, spin, and tomography”

QUARK-GLUON TOMOGRAPHY

COLLABORATION

DOE/NP topical collaboration

29 Principal Investigators
3 Affiliated Members

12 Universities

- Duke University
- Hampton University
- MIT
- Penn State University Berks
- Stony Brook University
- Temple University
- University of Arizona
- University of Connecticut
- University of Kentucky
- University of Maryland
- University of Washington
- William & Mary

3 National Labs

- Argonne National Lab
- Jefferson Lab
- Lawrence Berkeley National Lab

Principal Investigator:
Martha Constantinou (Temple University)

Additional Spokespersons:
Ian Cloët (Argonne National Lab)
David Richards (Jefferson Lab)
Feng Yuan (Lawrence Berkeley National Lab)

Executive committee:
Christopher Monahan (William&Mary)
Nobuo Sato ((Jefferson Lab))
Spokespersons

Co-Investigators:
Yong Zhao (Argonne National Lab)
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Wally Melnitchouk, Christian Weiss (Jefferson Lab)
William Detmold, John Negele, Phiala Shanahan, Iain Stewart (MIT)
Leonard Gamberg, Alexei Prokudin (Penn State University Berks)
Sergey Syritsyn, Edward Shuryak, Ismail Zahed (Stony Brook University)
Andreas Metz (Temple University)
Sean Fleming (University of Arizona)
Peter Schweitzer (University of Connecticut)
Keh-Fei Liu (University of Kentucky)
Xiangdong Ji, Kyle Shiells (University of Maryland)
Gerald Miller (University of Washington)
Konstantinos Orginos (William & Mary)

Affiliated Senior Investigators:
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Graduate Students:
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Postdoctoral Fellows:
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Joe Karpie, Colin Egerer (Jefferson Lab)
Kyle Lee (MIT)
Fatma Aslan (University of Connecticut)
Raza Sabbir Sufian, Bigeng Wang (University of Kentucky)

Research Associates:
Adam Freese (University of Washington)

Planned activities to support and promote Early Career Scientists

- Postdoc and bridge appointments
- Collaboration meetings
- Summer schools

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Lattice QCD

- Long-standing expertise in numerical methods in lattice gauge theories, simulations of QCD, non-perturbative methods for renormalization
- Investigations of hadron structure via parton distribution functions and generalizations through: (a) Mellin moments method, (b) novel approaches

Theory

- Specialization in designing and using effective field theories, chiral perturbation theory, perturbative QCD, and models of QCD
- Hadron structure-related investigations, e.g., QCD factorization, factorization breaking effects, lepton-nucleon interactions, light-front gauge topology

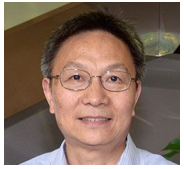
Phenomenology

- Broad expertise in developing frameworks for global analysis of experimental data sets, data science techniques, and analytical studies of aspects of QCD
- Studies of non-perturbative bound-state problems, chiral effective theories, and the interface of lattice QCD and hadron phenomenology

Involvement of JLab's theory group







QUARK-GLUON TOMOGRAPHY COLLABORATION

pheno working groups

1. **Machine Learning**
2. **GUMP**
3. **Nuclear GPDs**

Machine Learning WG

- Numerical implementation of GPD evolution, DVCS observables beyond LO in pQCD (synergies with theory WG)
- Develop machine learning based frameworks for GPD/CFF inference
  - Accelerated frameworks using GPUs
  - ML's imaging techniques for physics extraction (CFF/GPS) via generative modeling
- Global analysis of CFFs -> GPDs. (synergies with LQCD WG)

Argonne National Lab
Ian Cloet (staff)
Eric Moffat (postdoc)
Patrick Barry (postdoc)

Jefferson Lab
NS (staff)
Wally Melnitchouk (staff)
Christopher Coccuza (postdoc)
Marco Zaccheddu (postdoc)

Temple
Andreas Metz (Prof.)

Penn State Berks
Leonard Gamberg (Prof.)
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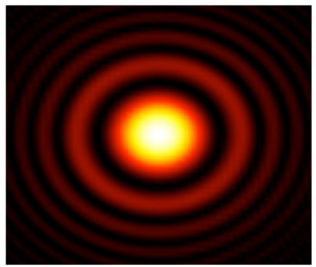
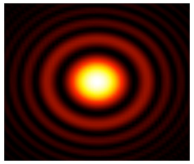
Lillie Mohn (undergraduate - engineering)
Owen Page (undergraduate - physics)

“Femtoscale Imaging of Nuclei using Exascale Platforms”



QuantOm Collaboration

DOE/NP/ASCR SciDAC project



QuantOm Collaboration

PI: Ian Cloët (ANL)
Co-PI: Jianwei Qiu (JLab)
Co-PI: Wu-chun Feng (VT)

"Partnership with SciDAC institutes and DS/HPC researchers from universities"

Argonne NATIONAL LABORATORY

Jefferson Lab

FASTMATH

RAPIDS

VT

OLD DOMINION UNIVERSITY

Senior Investigators

Name	Affiliation
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Julie Bessac (FASTMath)	Argonne National Lab
Taylor Childers	Argonne National Lab
Emil Constantinescu (FASTMath)	Argonne National Lab
Markus Diefenthaler	Jefferson Lab
Anshu Dubey (RAPIDS)	Argonne National Lab
Hanqi Guo (RAPIDS)	Argonne National Lab
Sylvester Joosten	Argonne National Lab
Yaohang Li	Old Dominion University
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Nesar Ramachandra	Argonne National Lab
Johann Rudi	Virginia Tech
Nobuo Sato	Jefferson Lab
Malachi Schram	Jefferson Lab
Xingfu Wu (RAPIDS)	Argonne National Lab

QuantOm Collaboration

Goals

- Build an event level physics analysis framework integrating theory and experimental simulation.
- R&D on scalable Machine Learning techniques embedded in the analysis framework
- Develop state-of-the art visualization for femtoscale imaging

Theory

- Work on QCD based factorization frameworks (PDFs, TMDs, GPDs)
- transforms parton degrees of freedom into phase space events

Experiment

- Experimental simulations
- Transform theory phase space events to realistic events

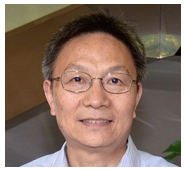
Math & Algorithmic development

- ML based analysis framework for PDFs, TMDs and GPDs extraction
- Workflows that can solve efficiently/accurately the domain problem

Computing and Visualization

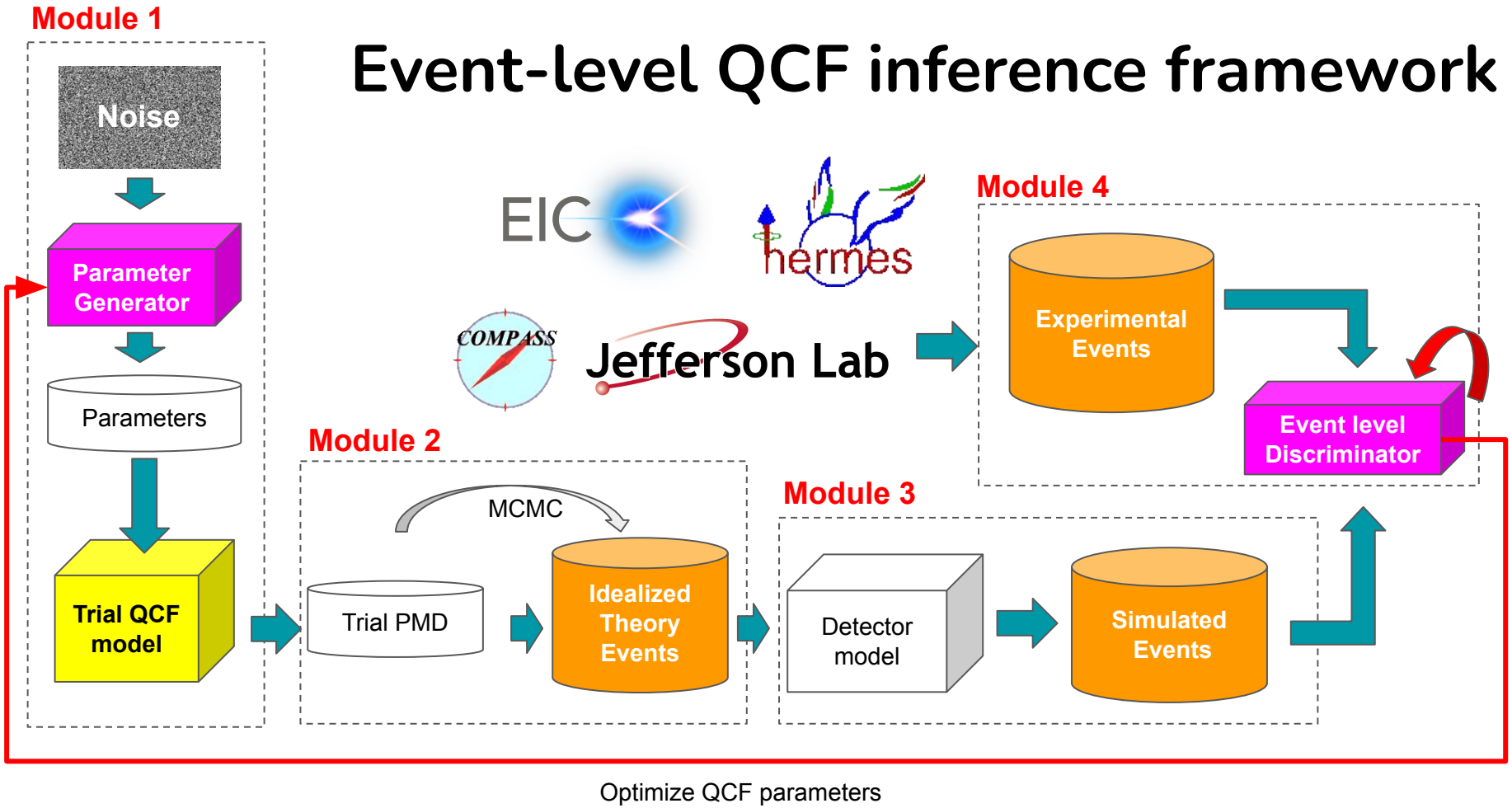
- Scalable solutions at supercomputing facilities and visualization for femtoscale imaging
- Code development for exascale computing

JLab involvement



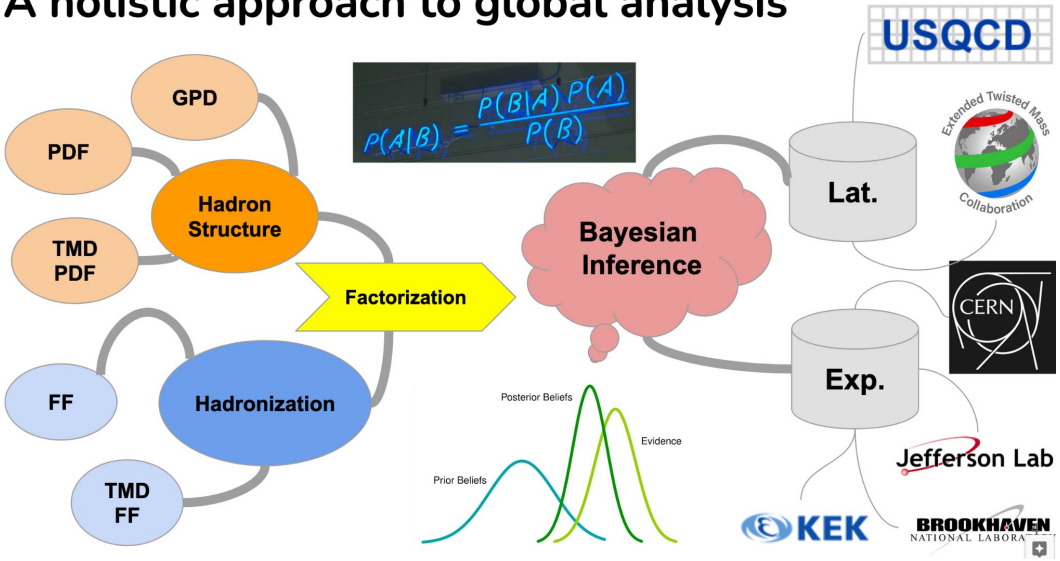



Event-level QCF inference framework



… and JAM!

A holistic approach to global analysis

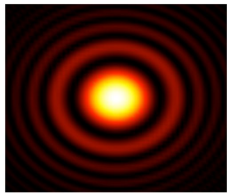


- Pioneering work in simultaneous global analysis framework of polarized & unpolarized PDFs and fragmentation functions
- Dedicated extension such as TMD extraction (nucleon tensorchar), meson structure, small x
- More recently, entering to a new phase synergistic activities with QGT and QuantOM collaborations

Summary

- Coordinated efforts to support the science mission of the JLab 12 GeV program and its potential 22 GeV upgrade has started.
- Integrate **theory**, **experiment**, **data science** and **high performance computing** in the era of high luminosity experiments and exascale computing.
- Develop the next generation of QCD analysis framework/tools for nuclear tomography.
- Train the next generation of scientists and prepare for EIC.

PHENOMENOLOGY
LATTICE QCD
THEORY
QUARK-GLUON TOMOGRAPHY COLLABORATION



QuantOm Collaboration