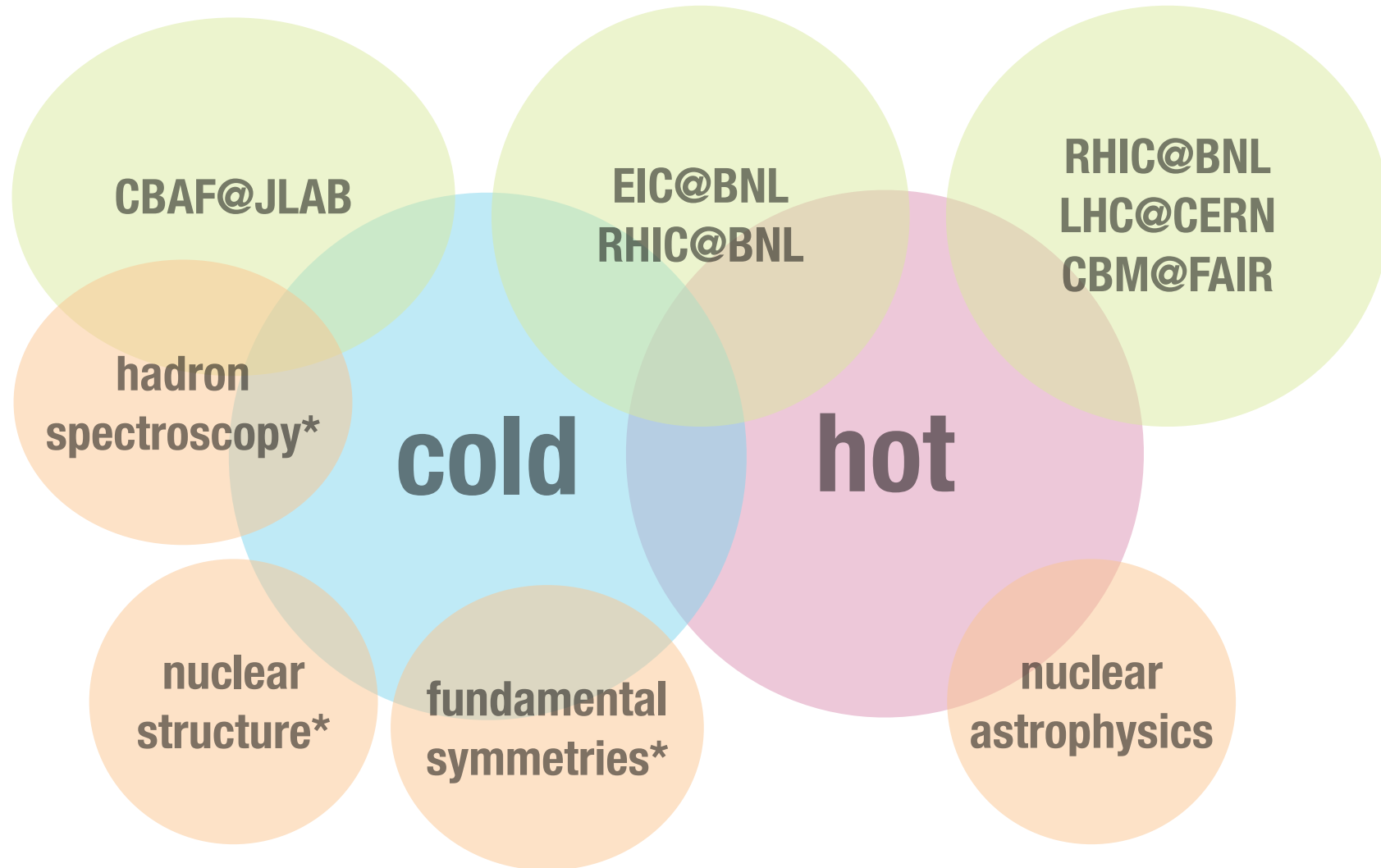


Computational QCD

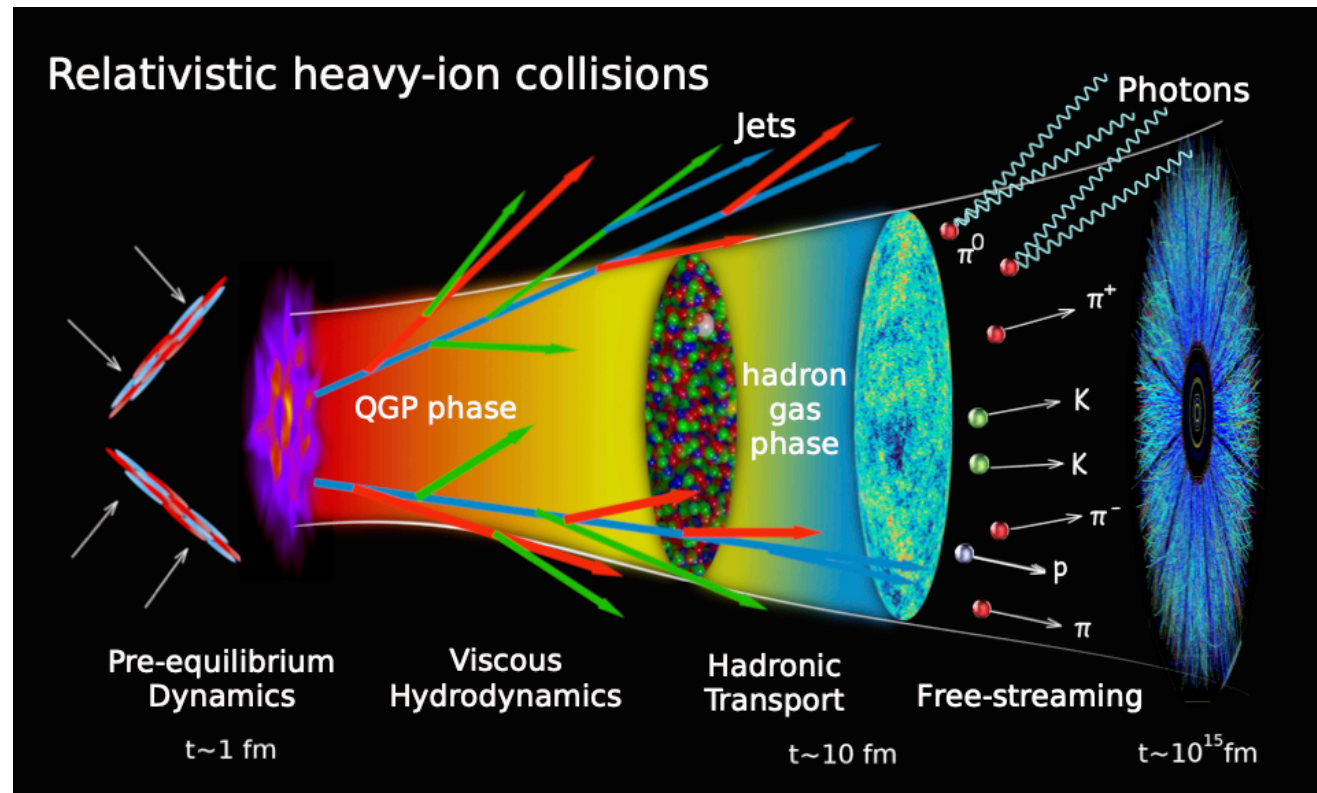
QCD community in US



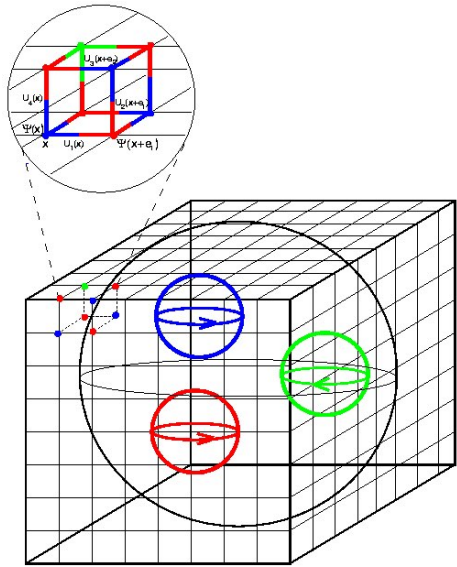
* covered by Detmold

hot QCD

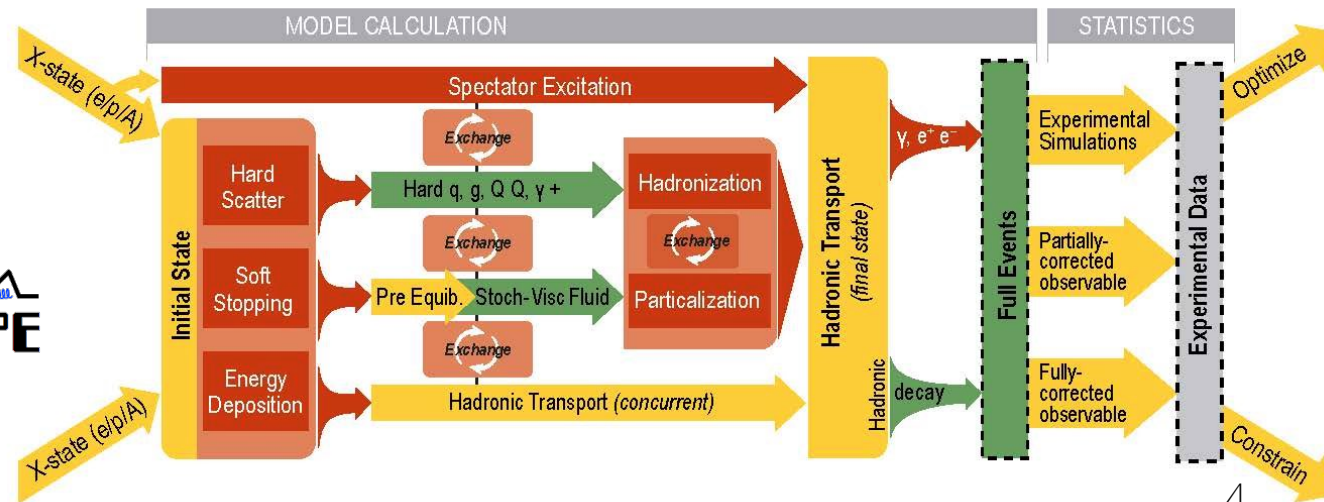
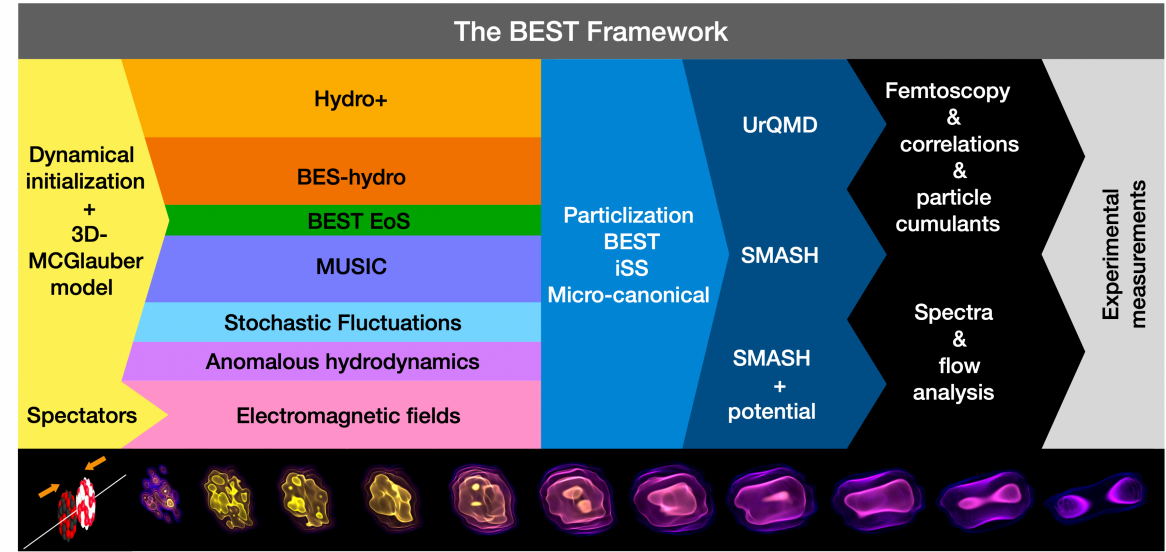
recreate and characterize new and predicted forms of matter and other new phenomena that might occur in extremely hot, dense QCD matter



computing at every stage

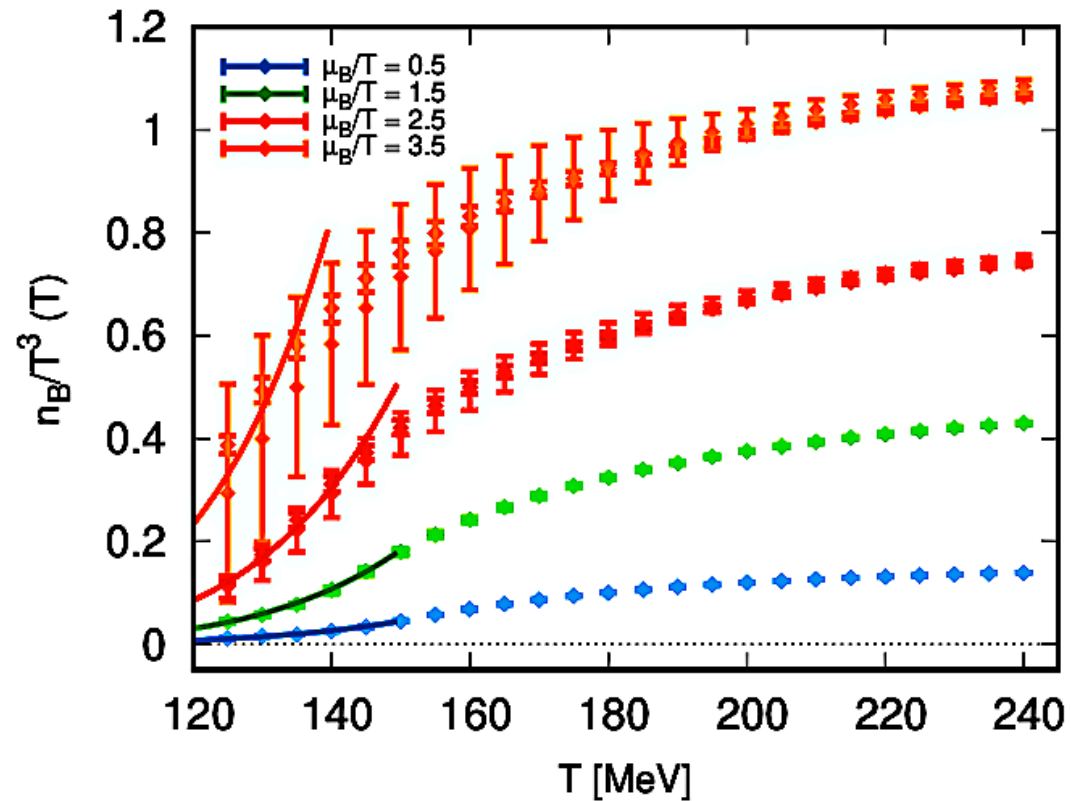


lattice QCD: QCD inputs



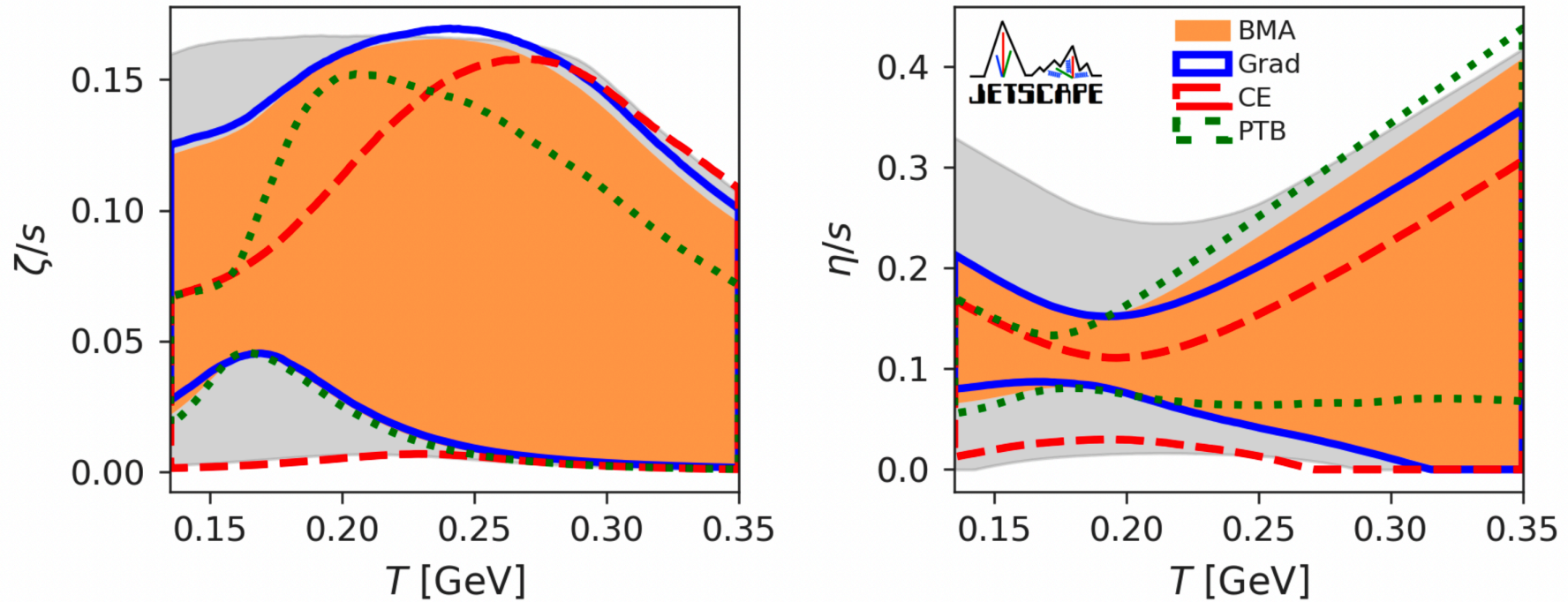
lattice QCD input:

equation of state of hot, dense QCD matter



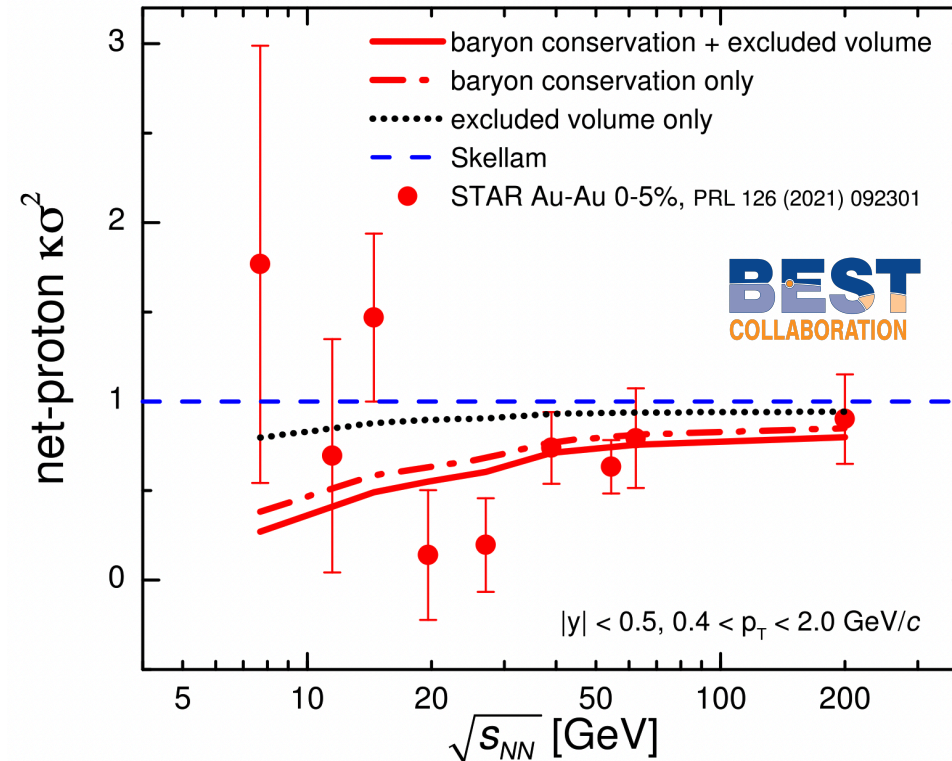
Borsanyi et.al., Phys. Rev. Lett. 126, 232001 (2021)

QGP characterization: temperature dependence of bulk and shear viscosities



D. Everett *et al.*, Phys. Rev. Lett. 126, 242301 (2021)

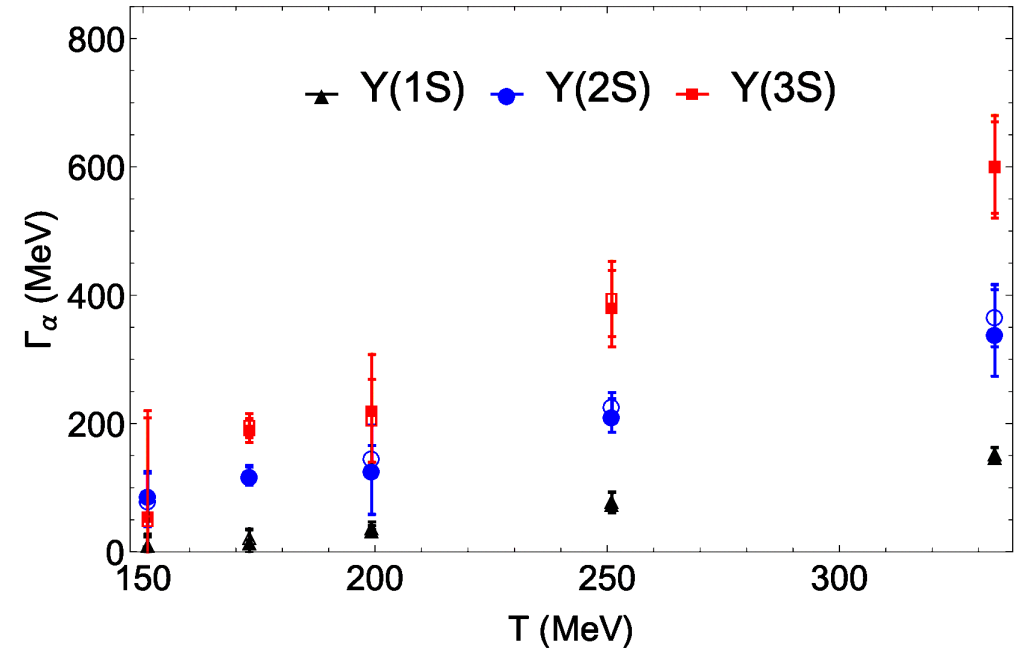
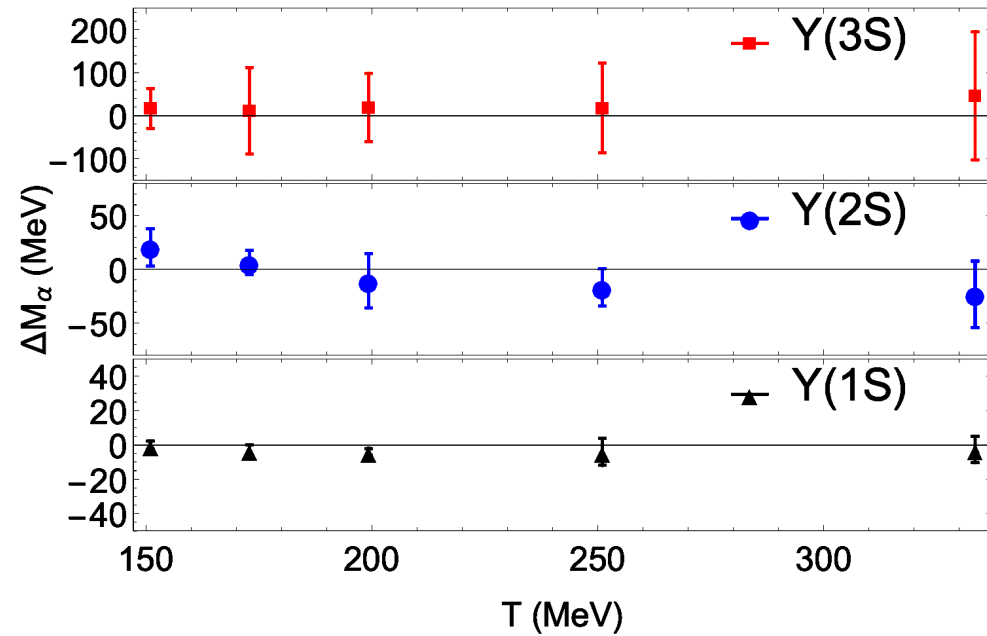
phenomenological postdiction: collision energy dependence of net proton kurtosis



Vovchenko *et al.*, Phys. Rev. C 105, 014904 (2022)

lattice QCD inputs:

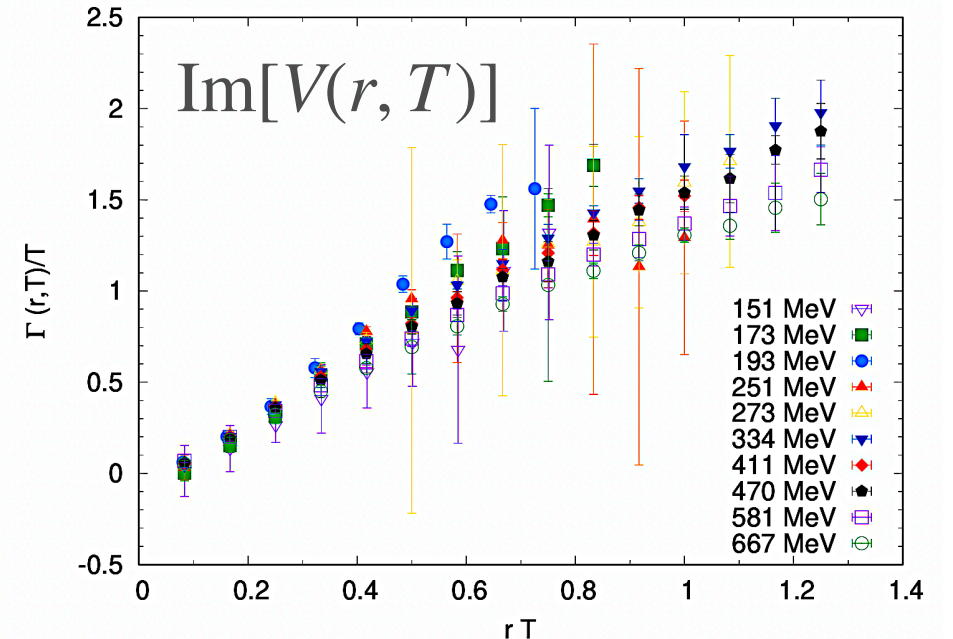
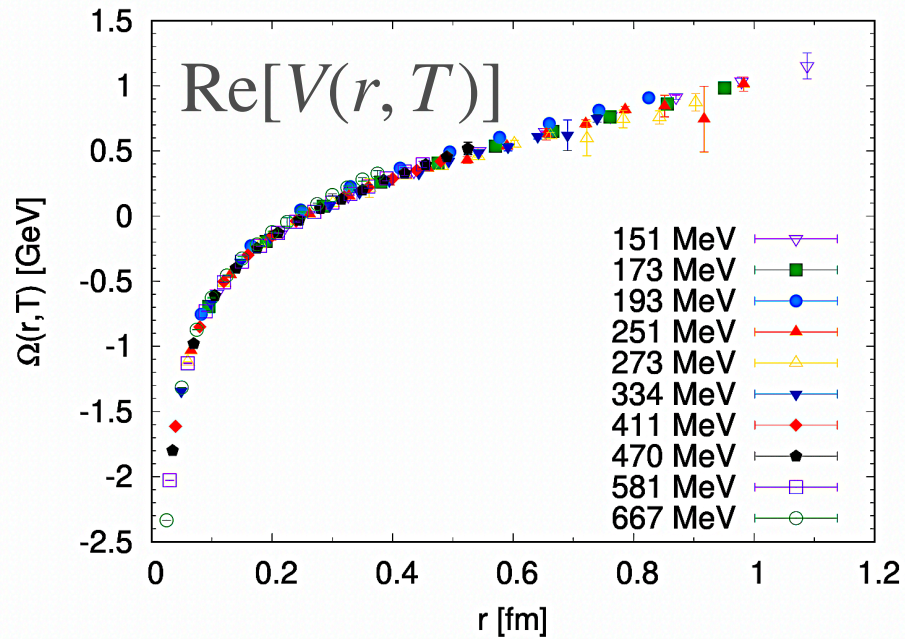
mass shift and thermal widths of excited bottomonia



Rasmus Larsen *et al.*, Phys. Lett. B800, 135119 (2020)

lattice QCD inputs:

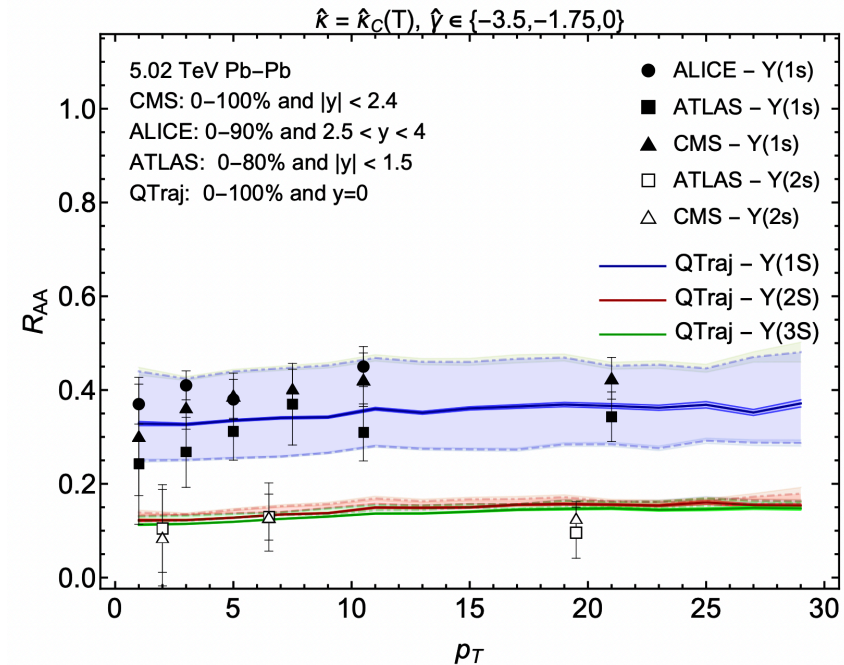
in-medium complex static quark potential



no color screening ?

phenomenological postdictions:

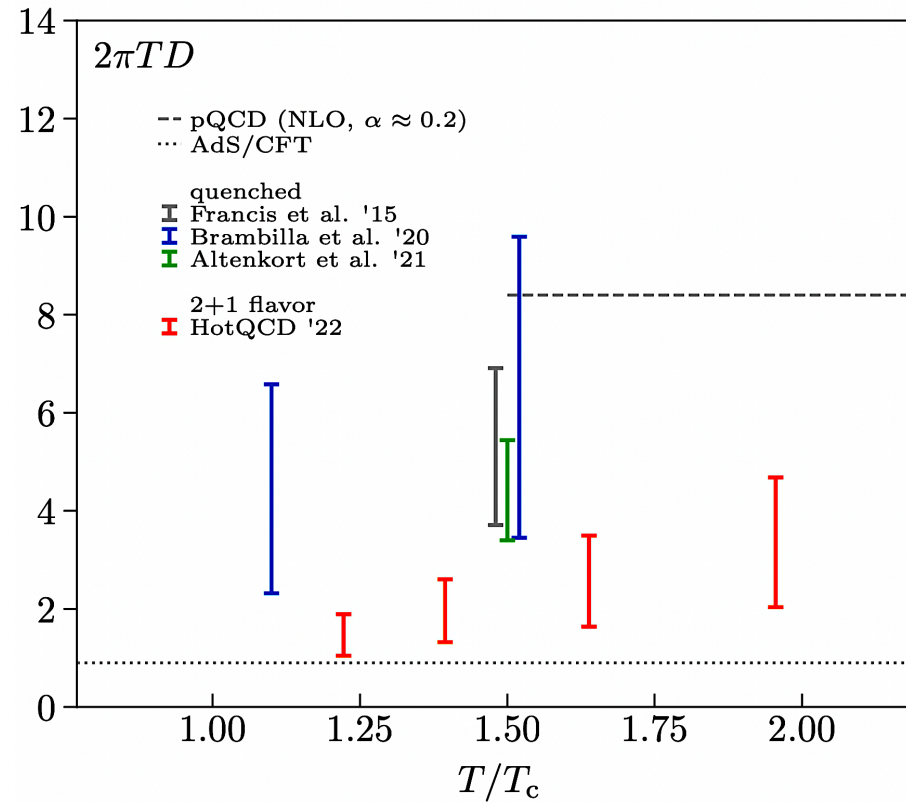
nuclear modification factors of Upsilon



open quantum system simulation

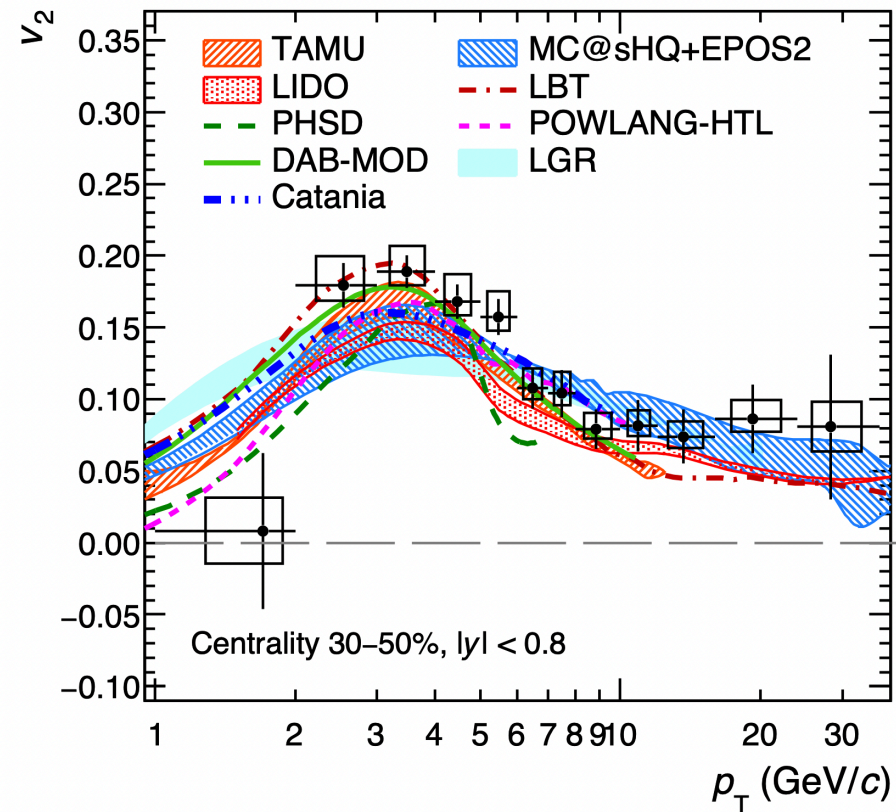
M. Strickland *et al.*, Phys. Rev. D105, 054513 (2022)

lattice QCD input: heavy quark diffusion constant



Luis Altenkort *et al.*, Quark Matter 2022

phenomenological postdictions: anisotropic flow of D mesons



ALICE Collaboration, JHEP 01, 174 (2022)

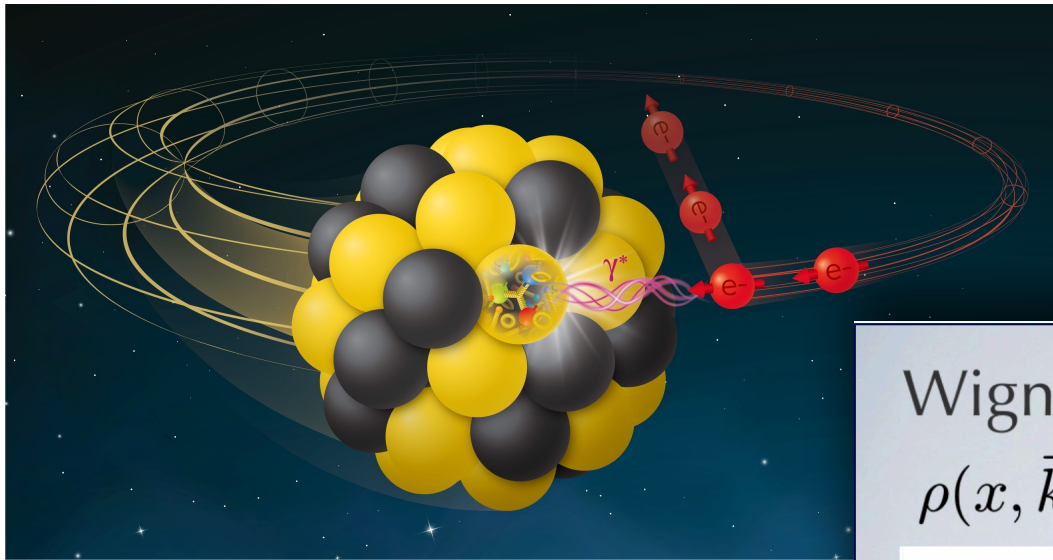
hot lattice QCD long range plan

- sPHENIX, LHC: state-of-the-art lattice QCD results for heavy quarks in QGP
 - heavy quark diffusion constant
 - thermal masses and widths of quarkonia
 - complex static quark potential
- CBM: extend the reach of lattice QCD calculations to larger μ_B

cold QCD

how properties of existing matter arise from QCD

- how are partons inside the nucleon distributed in both momentum and position space?
- how do the nucleonic properties such as mass and spin emerge from partons and their underlying interactions?
- how do the confined hadronic states emerge from these quarks and gluons?
- how do the quark-gluon interactions create nuclear binding?
- what are the emergent properties of dense systems of gluons?



Wigner distributions

$$\rho(x, \vec{k}_T, \vec{b}_T)$$

*"phase space" distributions
of partons in a nucleon*

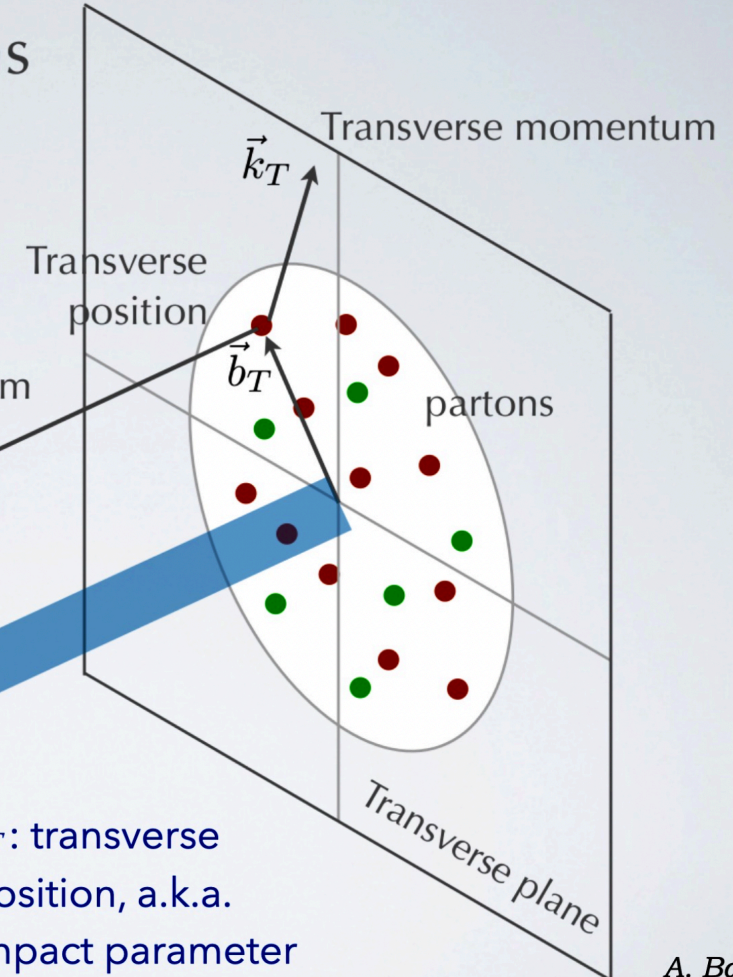
Longitudinal momentum

$$k^+ = xP^+$$

x : longitudinal
momentum
fraction carried
by struck parton

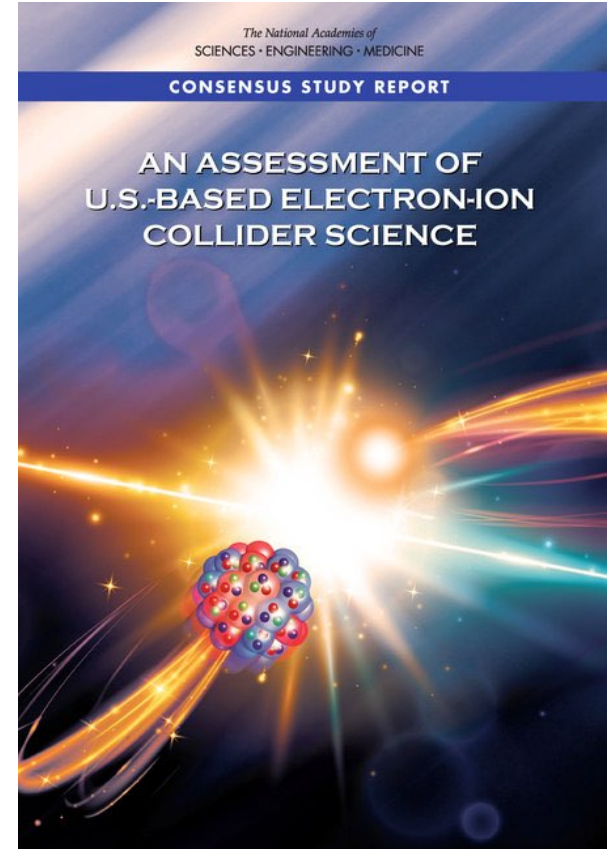


b_T : transverse
position, a.k.a.
impact parameter



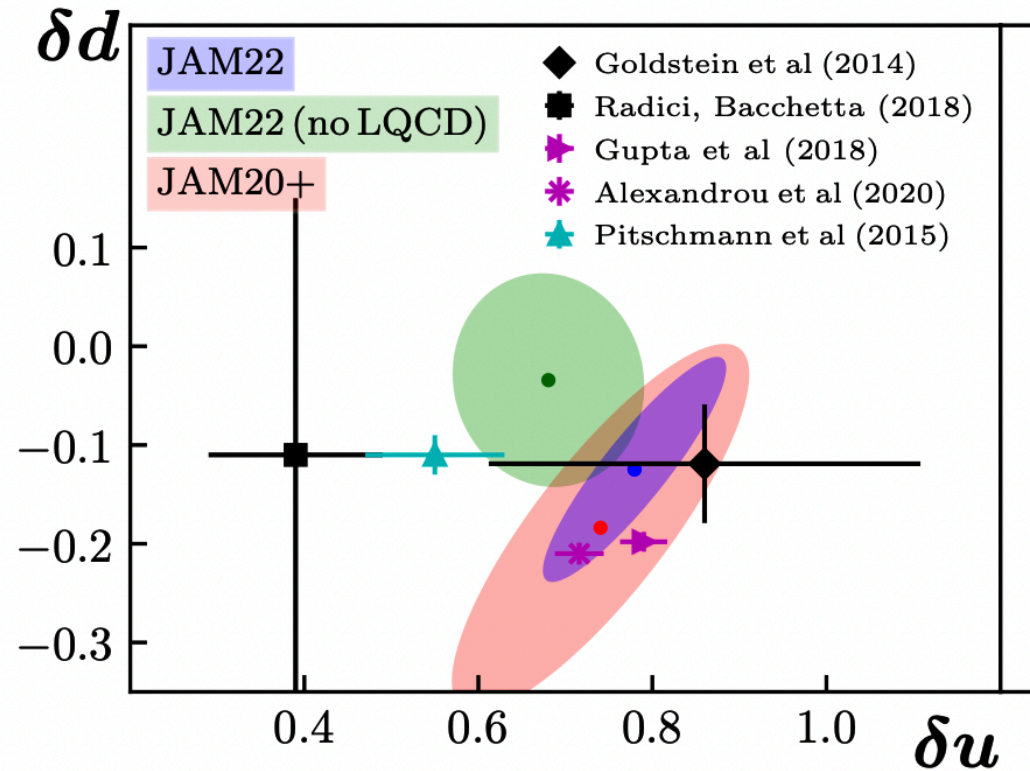
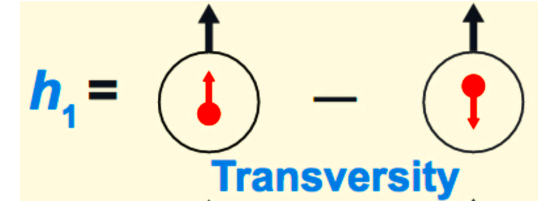
summary of National Academy of Sciences report on EIC

“The scientific challenges that would unfold with EIC require a robust theory program, not simply to design and interpret experiments, but also to develop the broad implications in an understanding of the quantum world, both through analytic theory as well as through **lattice QCD simulations on large-scale computers.**”



proton transversity function:

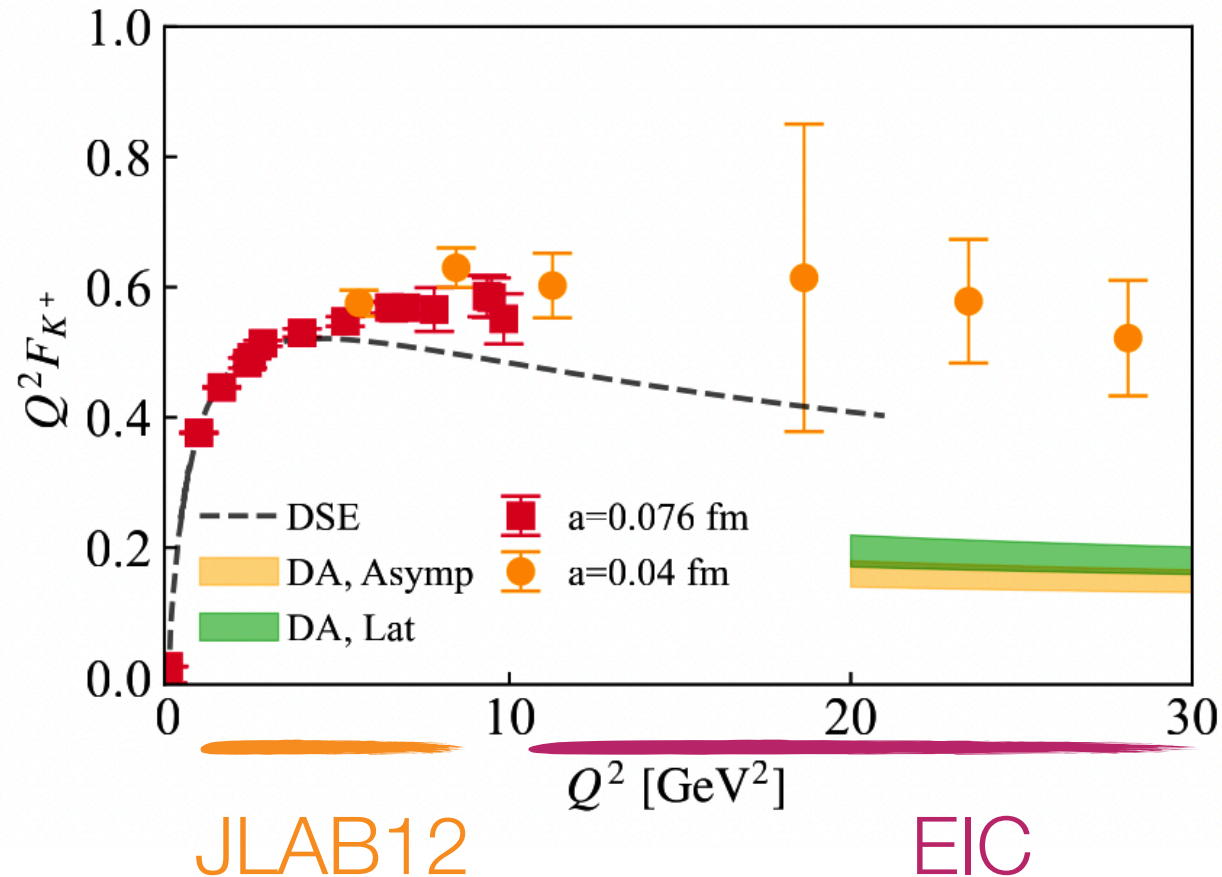
impact of LQCD tensor charge



JAM Collaboration, Phys. Rev. D106, 034014 (2022)

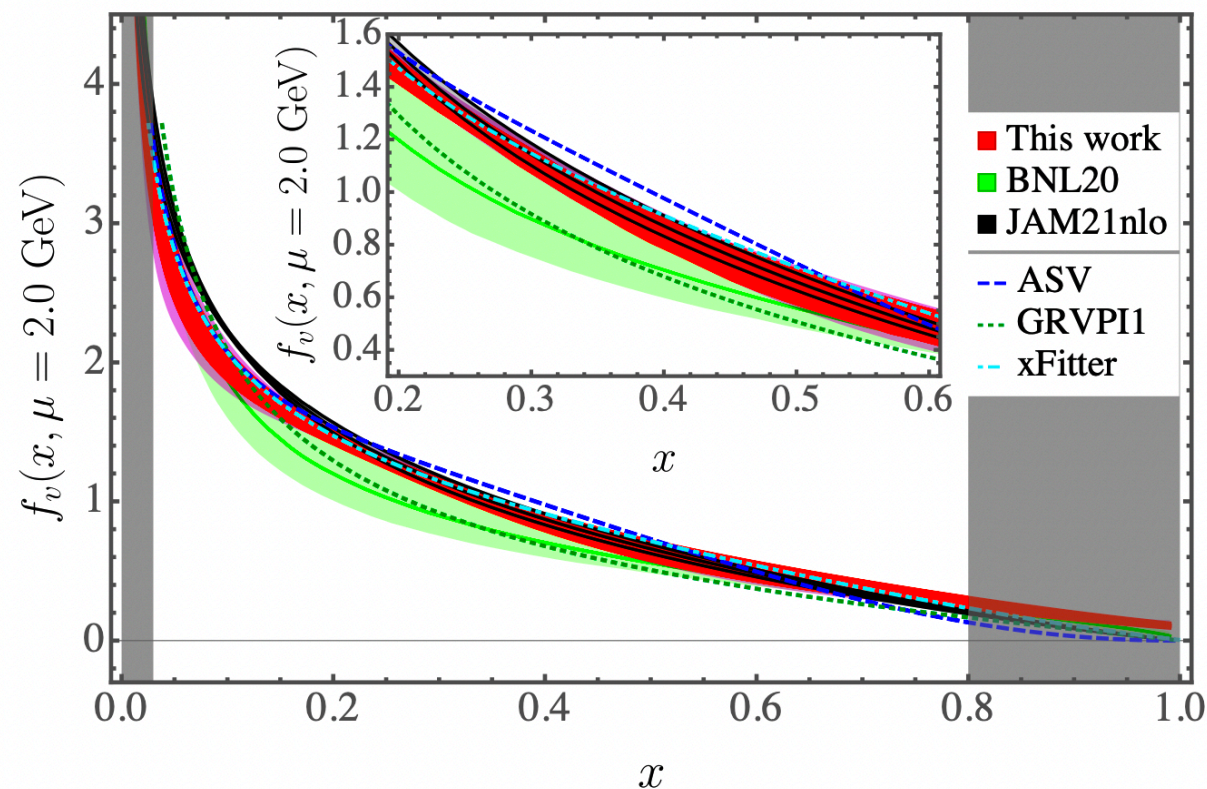
structure of QCD Goldstone bosons:

LQCD predictions for kaon electromagnetic form factor

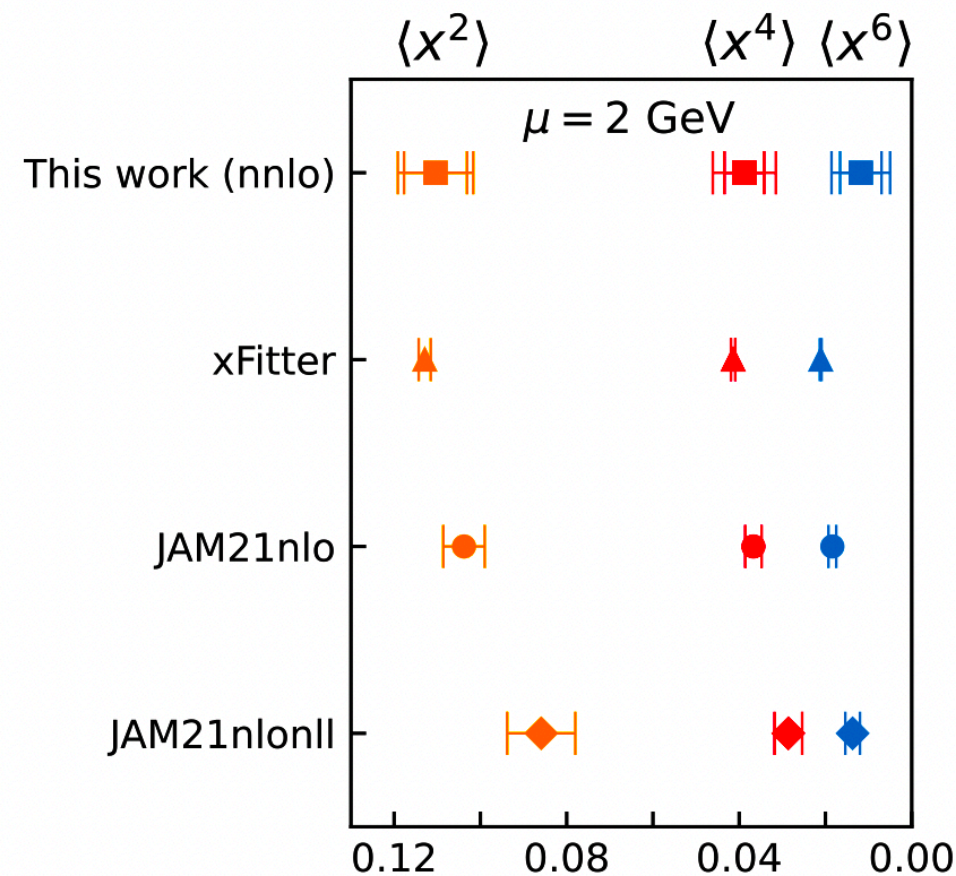


Xiang Gao *et al.*, in preparation

structure of QCD Goldstone bosons: valance parton distribution in pion



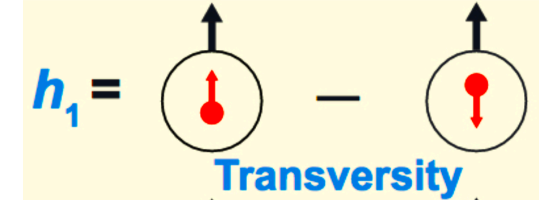
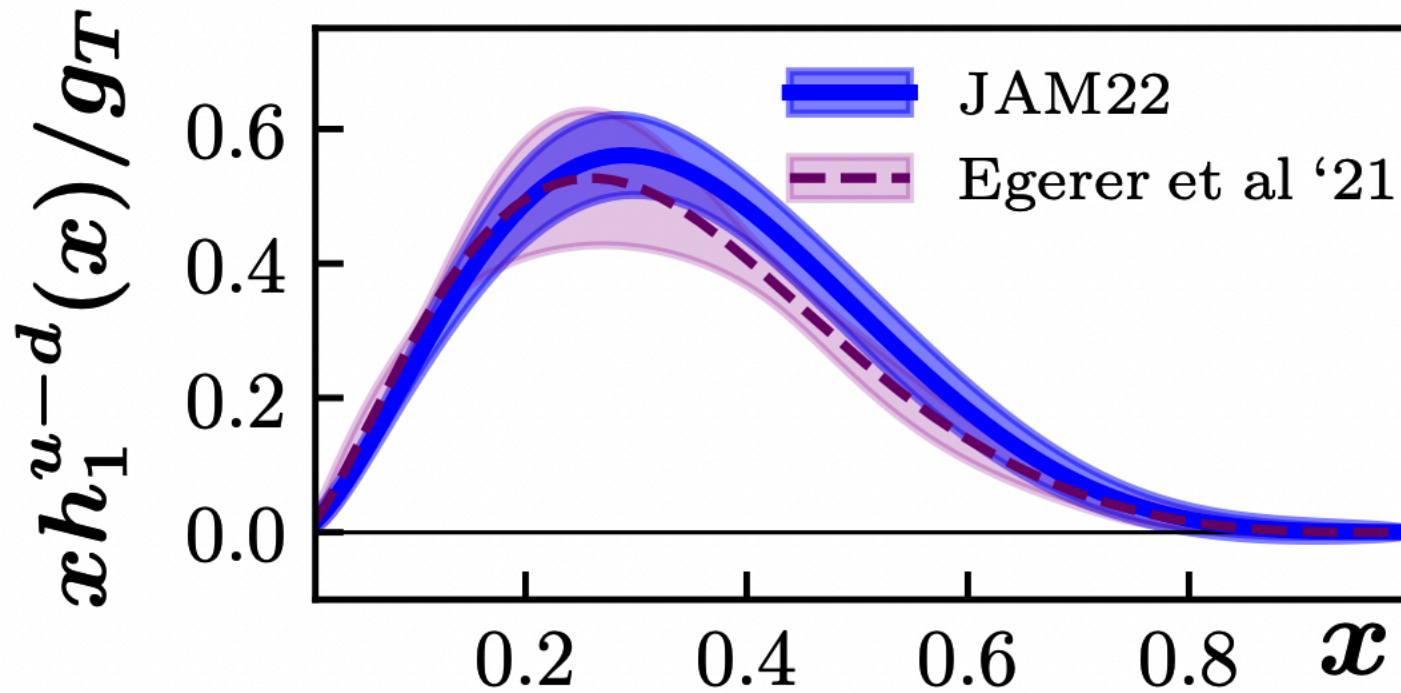
Yong Zhao *et al.*, Phys. Rev. Lett. 128, 142003 (2022)



Xiang Gao *et al.*, in preparation

proton transversity function:

LQCD prediction vs phenomenological extractions

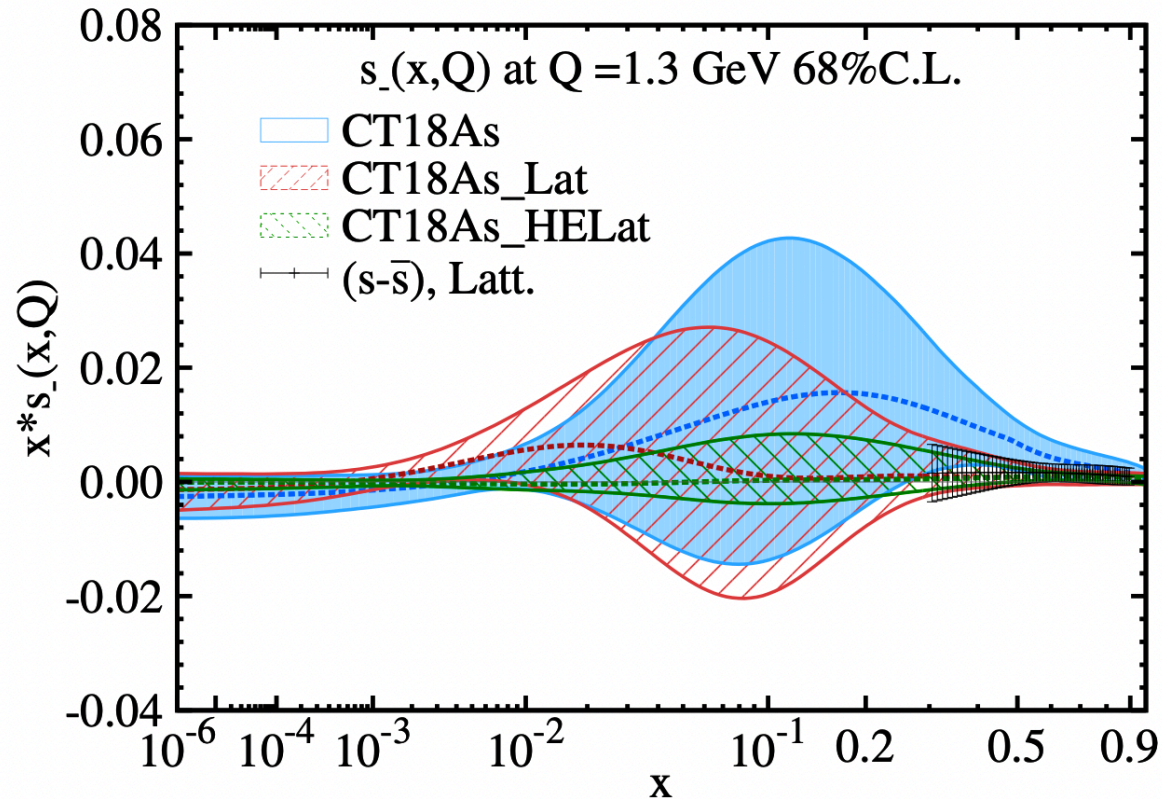


HadStruc Collaboration, Phys. Rev. D105, 034507 (2022)

JAM Collaboration, Phys. Rev. D106, 034014 (2022)

parton distribution of proton:

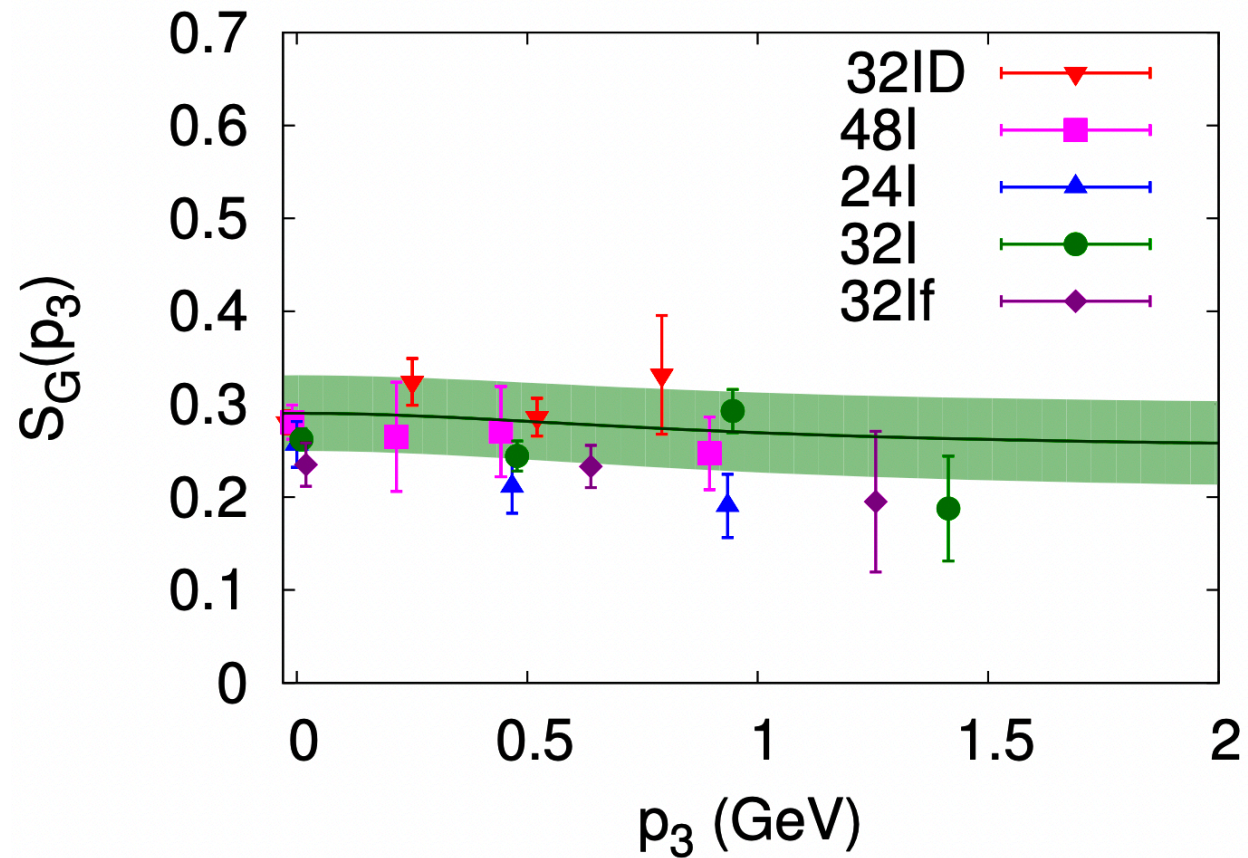
LQCD impact on strangeness asymmetry



H.-W. Lin *et al.*, 2204.07944; Phys. Rev. D104, 094511 (2021)

gluons in proton:

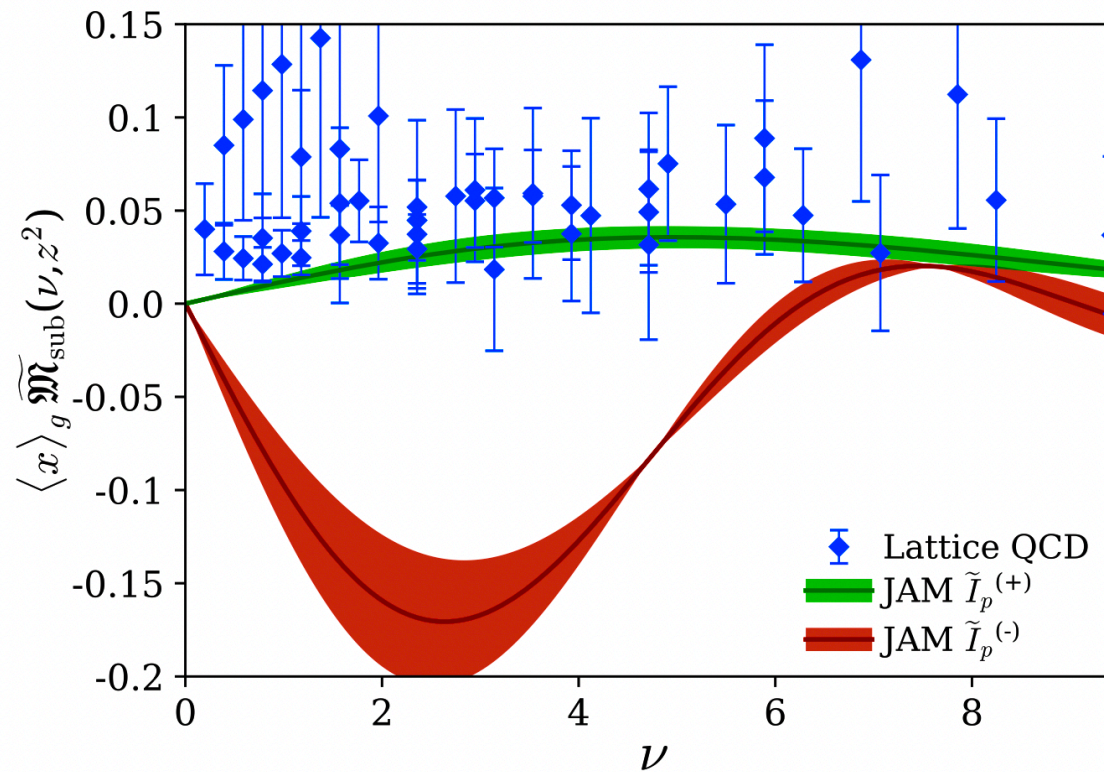
contributions of gluon helicity to proton spin



χ QCD Collaboration, Phys. Rev. Lett. 118, 102001 (2017)

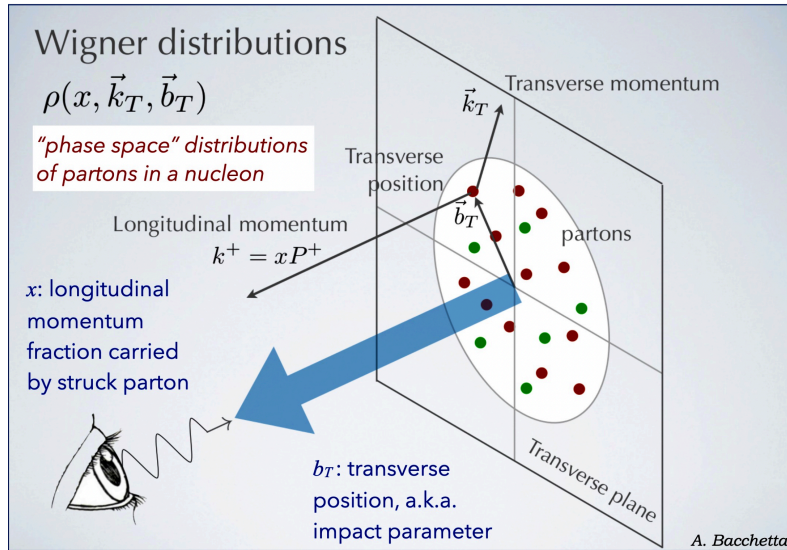
gluons in proton:

gluon helicity distribution

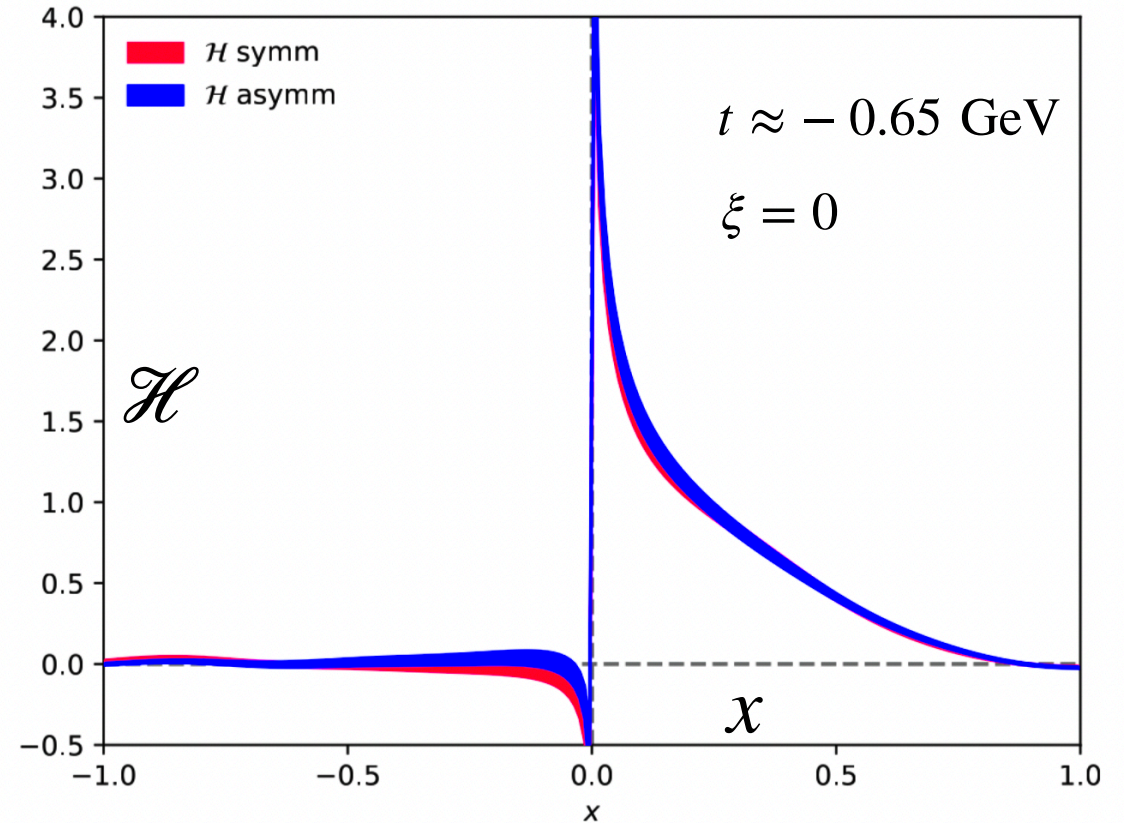


HadStruc Collaboration, 2207.08733

beyond 1D structure: generalized parton distribution

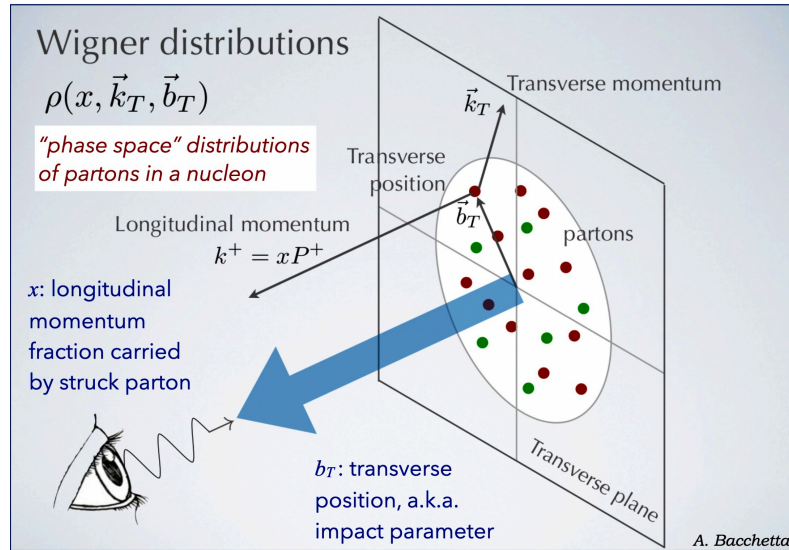


N/q	U	L	T
U	H		E_T
L		\tilde{H}	\tilde{E}_T
T	E	\tilde{E}	H_T, \tilde{H}_T

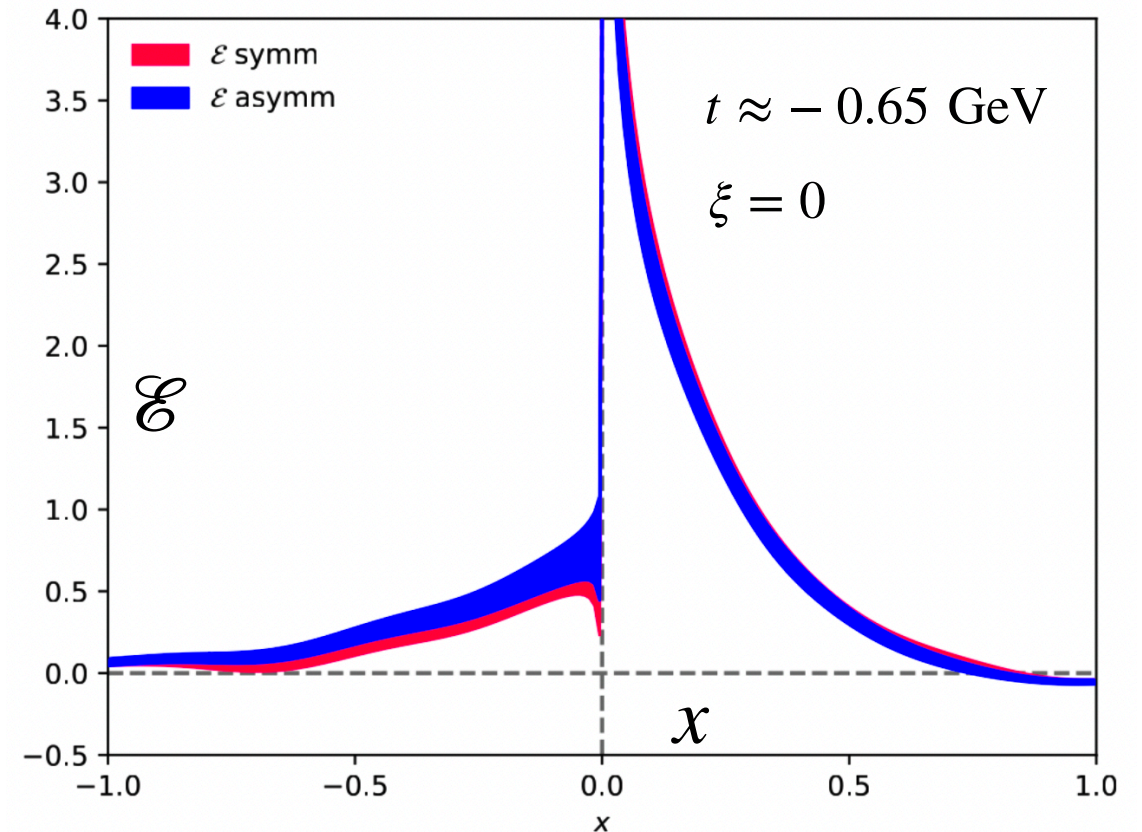


Bhattacharya, Constantinou, Zhao *et al.*, in preparation

beyond 1D structure: generalized parton distribution



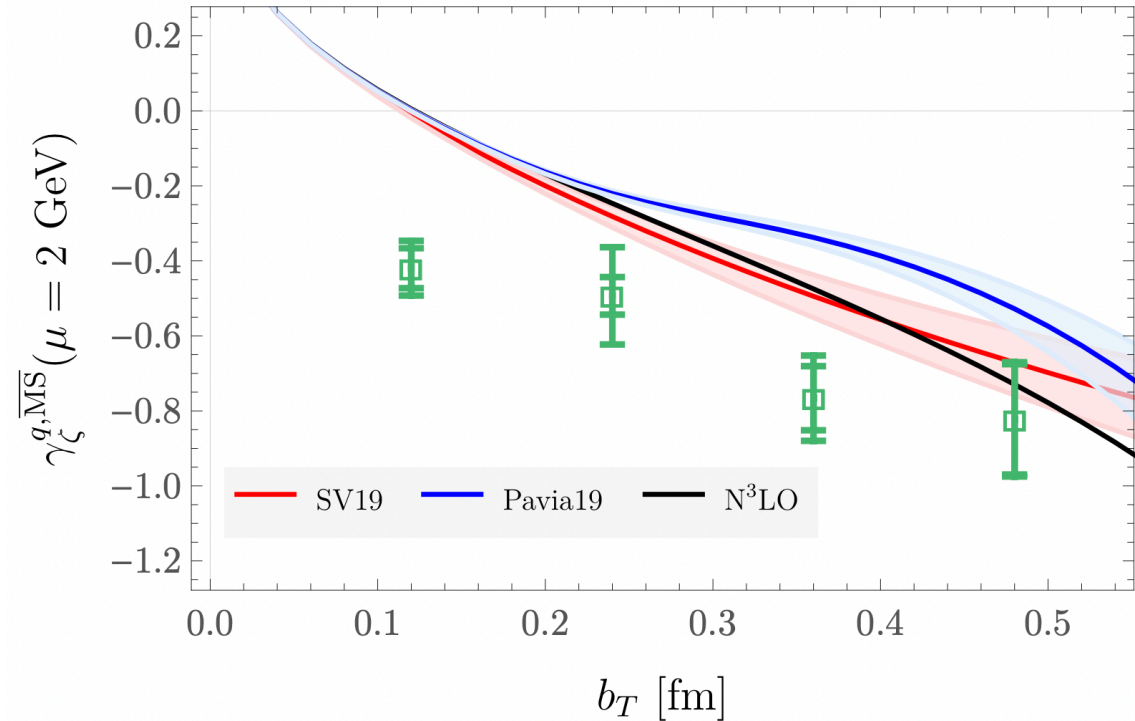
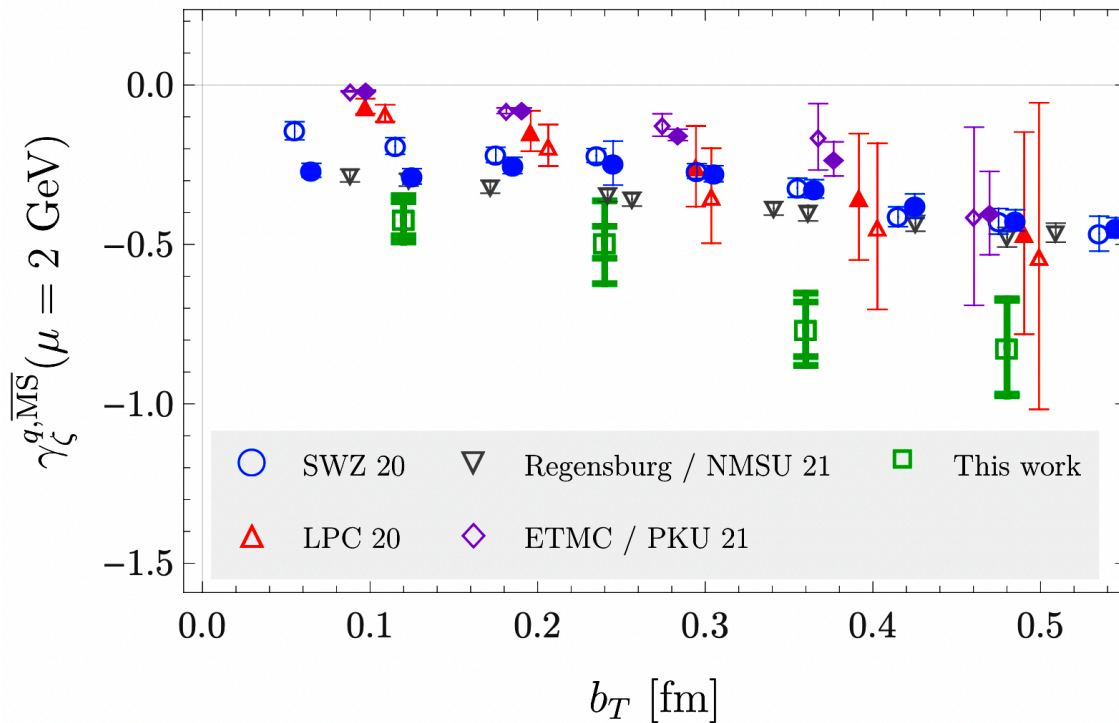
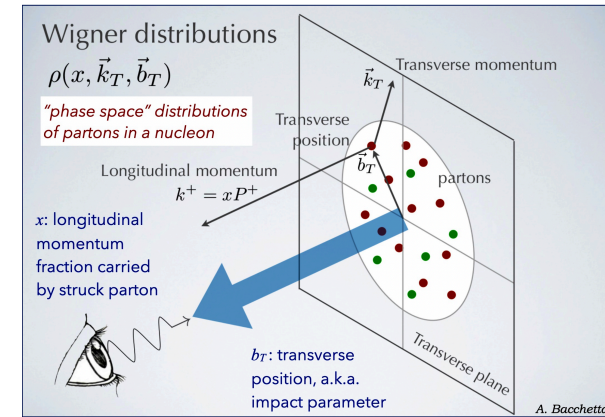
N/q	U	L	T
U	H		E_T
L		\tilde{H}	\tilde{E}_T
T	E	\tilde{E}	$H_T \tilde{H}_T$



Bhattacharya, Constantinou, Zhao *et al.*, in preparation

beyond 1D structure: transverse momentum dependent distribution

Collins-Soper kernel



Shanahan, Wagman, Zhao, Phys. Rev. D104, 114502 (2021)

cold lattice QCD long range plan

- JLAB12, EIC: generalized parton distributions
- JLAB12, EIC: transverse momentum dependent distributions
- EIC: gluon distributions
- EIC: push towards smaller x