## **Snowmass track: <u>Hadronic Tomography at the EIC</u>**

## ... and the Energy Frontier

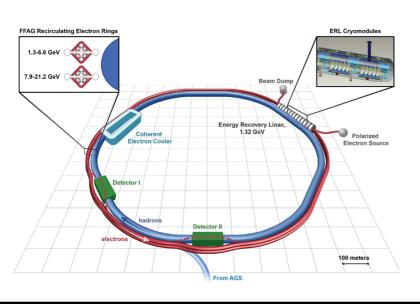
**Editors: Tim Hobbs with** 

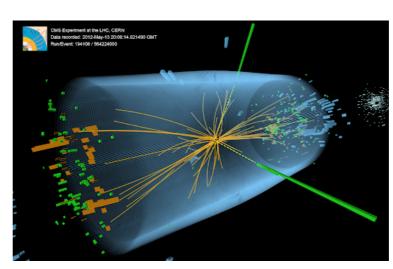
Salvatore Fazio, Alexei Prokudin, Alessandro Vicini

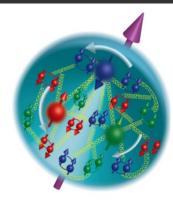
**26 January 2021** 

discussion toward Snowmass proceedings











## planning for Snowmass proceedings: drafting scheme

WHAT

broad representation of physics opportunities in tomography/HEP

- → 160+ LOI contributors over PDFs, GPDs, LHC TMD meas., ...
- → carry forward insights from EIC YR studies

BY WHOM

open to the full community, but organizing structure needed

- → identify critical sub-concentrations (PDFs, TMDs, ...)
- → designate relevant point-persons to help coordinate these aspects

HOW

we will begin assembling a master document to collate all relevant pieces

- $\rightarrow$  comprised of topical sub-documents; e.g., spin PDFs
- → open editing of these sub-docs, but curated by coordinators

WHEN

Snowmass convenors: initial document, ~March 1st

→ intended to evolve beyond March

supplementary material ———

#### Hadronic Tomography at the EIC and the Energy Frontier

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→ broad document representing multiple sub-communities

completed LoI available here

- focus: EIC determinations of partonic distributions (**PDFs**, **GPDs**, TMDs)
- tomography encompasses a wide range of EIC 
  ← HEP topics

## numerous 3D structure connections to LHC program/objectives

• PDFs and GPDs/TMDS: including helicity-odd M.E.s  $\sim \langle \gamma^+ \gamma_5 \rangle$ 

select topics

- <u>high-energy QCD</u> (DIS measurements; heavy quarks/masses, jets,  $\alpha_s$ )
- <u>gluonic structure/Higgs</u> (gluon PDF/GPD; improvements to gg→ h production)
- QED effects (photon PDF; improved EW corrections)
- <u>nuclear structure</u> (nuclear PDFs; connections to heavy-ion UPCs)

progress will depend on various <u>methods</u>

- → phenomenological studies; global analyses [of **PDFs**, **GPDs** ...]
- → continuum QCD approaches
- → lattice QCD input
- → AI/machine-learning and MCEGs

# measuring hadron's multi-dimensional structure at the EIC

extract unintegrated matrix elements from data:

[schematic]

$$W(x, \vec{b}_T, \vec{k}_T) \sim \langle \gamma^+, \gamma^+ \gamma_5 \rangle$$
 e.g., Wigner distribution

→ related to other distributions via projections,

$$f(x, \vec{k}_T) = \int d^2 \vec{b}_T W(x, \vec{b}_T, \vec{k}_T)$$
 TMD  $f(x) = \int d^2 \vec{k}_T f(x, \vec{k}_T)$  PDF

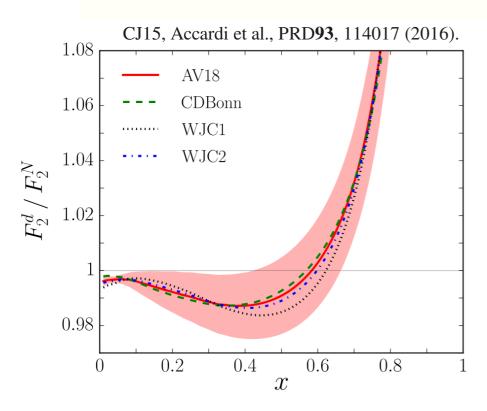
this generalizes to helicity-odd distributions; GPDs; also, light nuclei!

- precision goals at HL-LHC depend partly on hadron structure information
  - → PDFs, GPDs → SM predictions in hadronic collisions
  - → tomography will be a collaborative theme between EIC/LHC

# importance of nuclear data in free nucleon QCD analyses

#### information involving light nuclei

the d-quark is predominantly determined from deuterium data with model-dependent nuclear correction(s):  $f^{q/d} = f^{q/N} \otimes f^{N/d}$ 



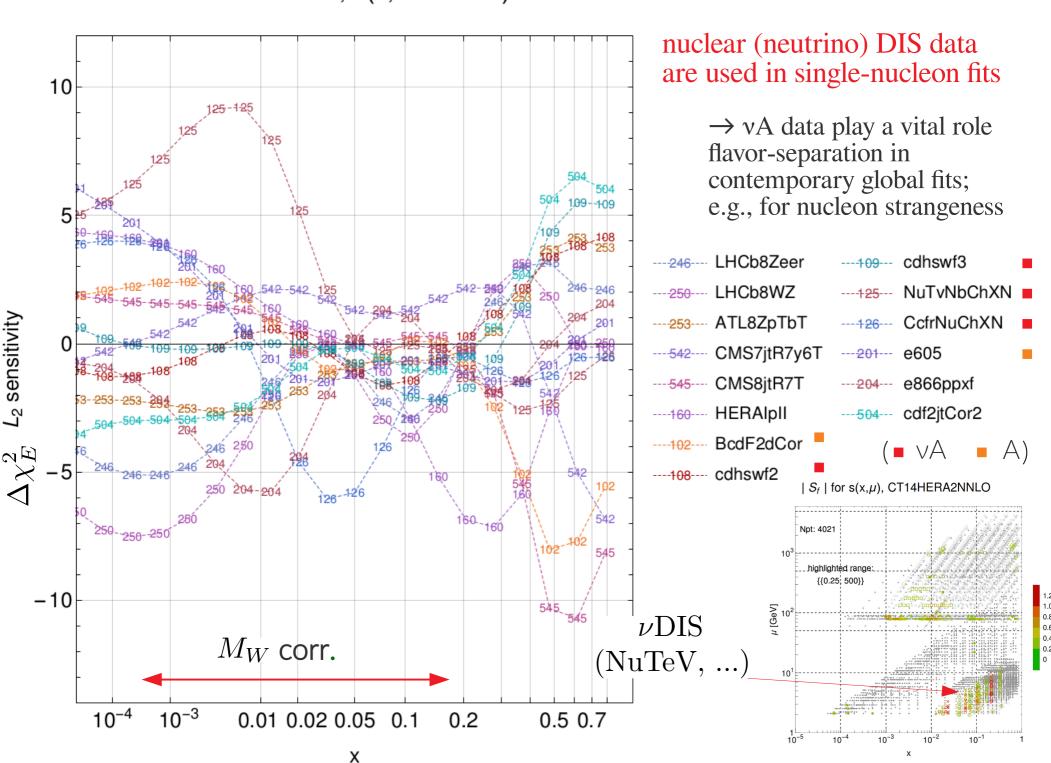
$$F_2^{e^- n} \sim x(4d + u)/9$$

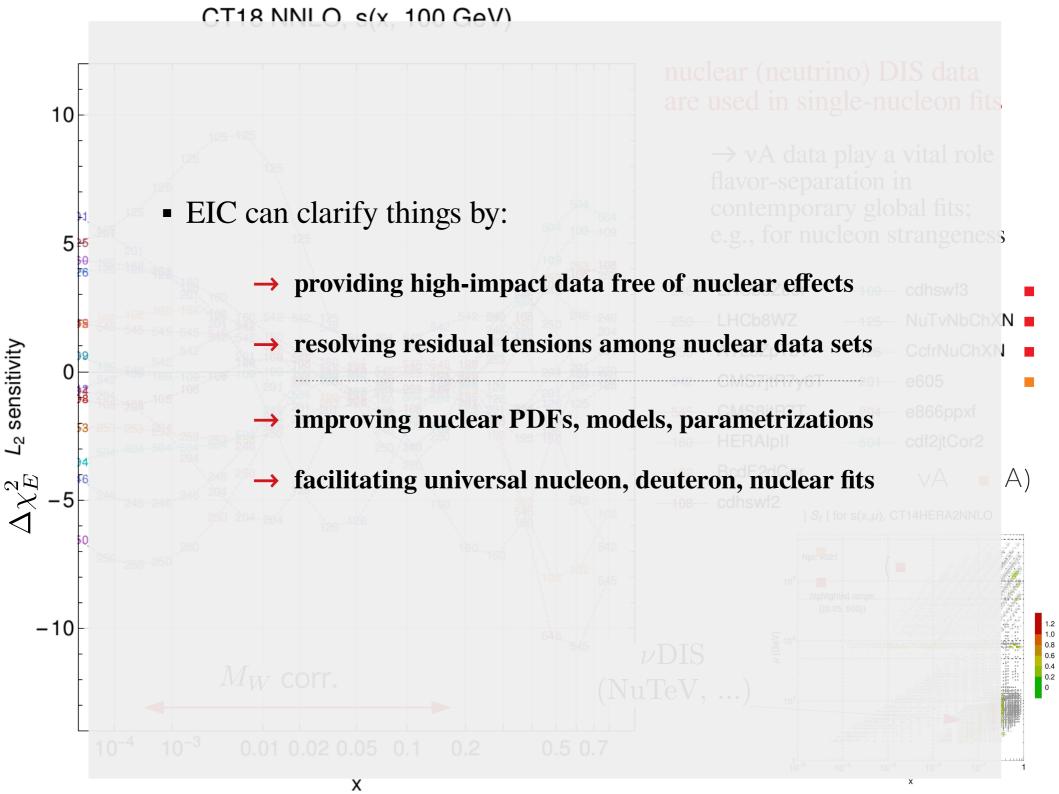
nuclear uncertainties and corrections can propagate to free-nucleon PDF determinations...

...and theory predictions at the LHC

#### heavy nuclear targets

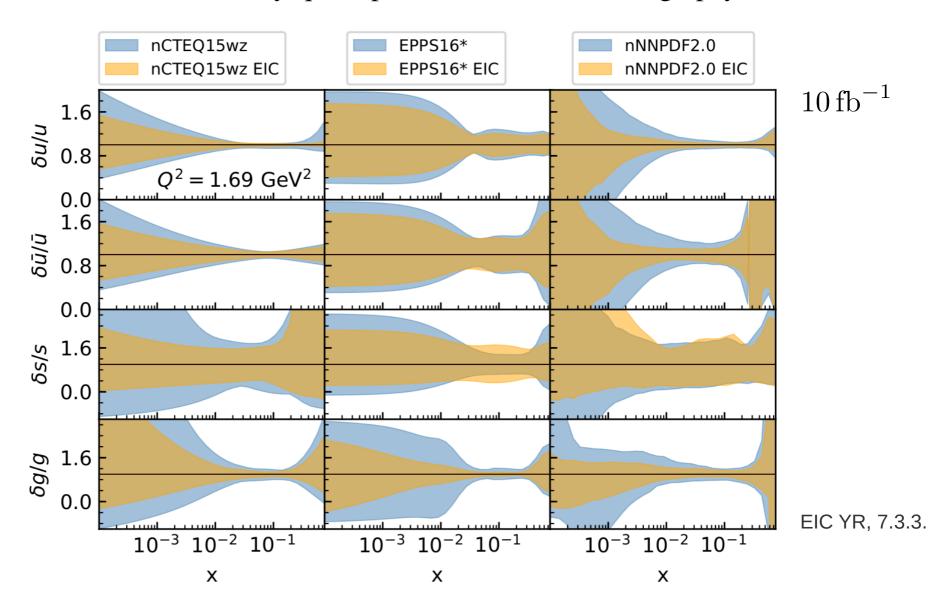
→ additional flavor separation often provided by nuclear DIS, including neutrino scattering





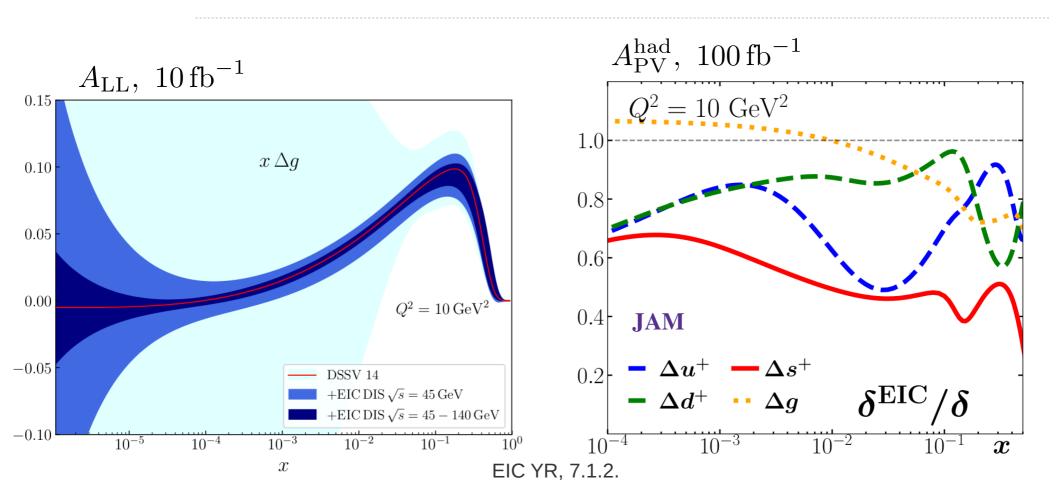
# EIC potential impact on nPDFs

- inclusive charged-lepton nuclear-DIS data have significant impact (Au, below)
- additional avenues: heavy-quark production; nuclear tomography data



# EIC possibilities with spin-polarized PDFs

- EIC will record data in multiple channels to constrain spin-PDFs (below)
- independent measurements of helicity-odd GPDs and spin-dependent TMDs can provide additional constraint(s)
- interactions with lattice QCD in EIC era



## further thoughts, moving forward

- EIC tomography LOI wraps multiple topics
  - → dedicated studies or contributions may be natural
  - → must coordinate these efforts/inputs
  - → lessons from EIC YR studies should be included

[also opportunities for extension studies]

more effort required to develop phenomenlogical implications

# thanks