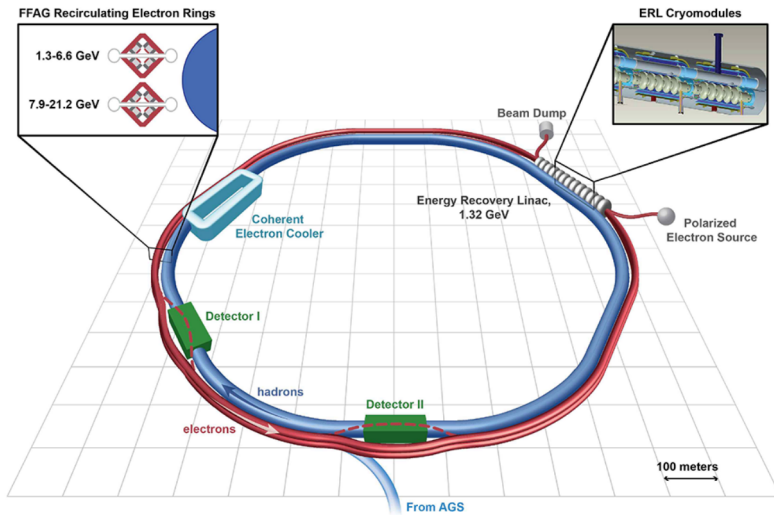# Snowmass 2021 Letter of Interest: <u>Hadronic Tomography at the EIC</u>
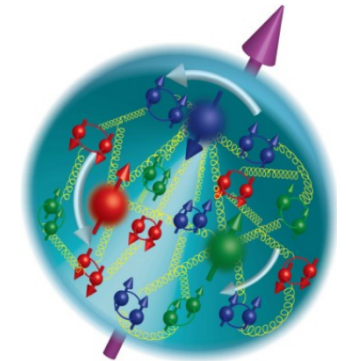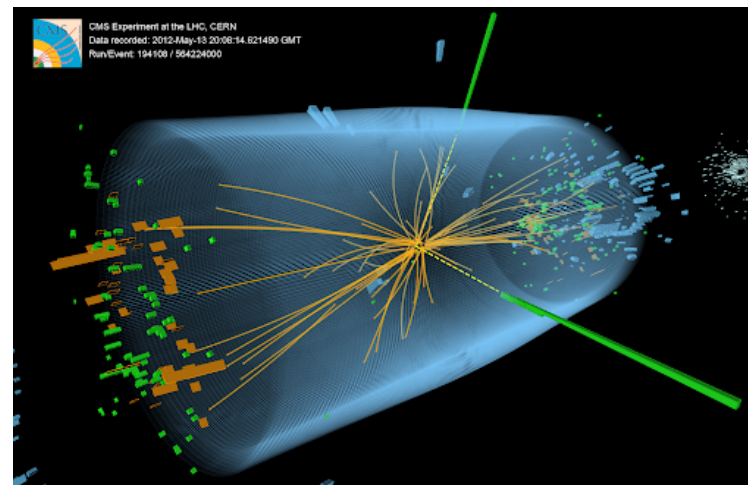
<u>… and the Energy Frontier</u>

Editors: Salvatore Fazio, <u>Tim Hobbs</u>, Alexei Prokudin, Alessandro Vicini

28 October 2020

160+ coauthors/signers!

Hadronic Tomography at the EIC and the Energy Frontier

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→ document/effort enjoys significant community support

completed LoI available <u>here</u>

- focus: EIC determinations of partonic distributions (**<u>TMDs</u>**, GPDs, PDFs)

- tomography therefore encompasses a wide range of EIC ↔ HEP topics

measuring hadron's multi-dimensional structure at the EIC

- extract unintegrated matrix elements from data:　　　　　　　　　[schematic]

$$W(x, \vec{b}_T, \vec{k}_T) \qquad e.g., \text{ Wigner distribution}$$

　→ related to other distributions via projections,

$$f(x, \vec{k}_T) = \int d^2 \vec{b}_T\, W(x, \vec{b}_T, \vec{k}_T) \qquad \text{TMD} \quad \bigstar \quad \text{(this meeting)}$$

$$f(x) = \int d^2 \vec{k}_T\, f(x, \vec{k}_T) \qquad \text{PDF}$$

...status of QCD factorization theorems, other theory investigations required

- precision goals at HL-LHC depend partly on hadron structure information

　→ PDFs, TMDs → SM predictions in hadronic collisions

　→ tomography will be a collaborative theme between EIC/LHC

- numerous 3D structure connections to LHC program/objectives

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- TMD measurements, precision EW physics (**TMDs** and M_W extractions)

- high-energy QCD (DIS measurements; heavy quarks/masses, jets, α_s)

- gluonic structure/Higgs (gluon PDF/GPD; improvements to gg→ h production)

- QED effects (photon PDF; improved EW corrections)

- nuclear structure (nuclear PDFs; connections to heavy-ion UPCs)

select topics

- progress will depend on various methods

→ phenomenological studies; global analyses [of **TMDs**, PDFs, ...]

→ continuum QCD approaches

→ lattice QCD input

→ AI/machine-learning and MCEGs

TMD issues in the EIC tomography LOI

- determinations of M_W from M_T and p_T distributions in LHC data

  $\rightarrow$ intrinsic parton-level transverse momentum affects extraction

  $\rightarrow$ improved TMD would reduce nonpertubative uncertainty

  e.g., Bacchetta, Bozzi, Radici, Ritzmann, Signori: PLB**788**, 542-545 (2019)

- TMD fragmentation functions

- TMD phenomenology

  $\rightarrow$ models (quark models, effective descriptions)

  e.g., Bacchetta, Celiberto, Radici, Taels: EPJC**80**, 733 (2020)

  $\rightarrow$ QCD analyses (e.g., N^{3}LL TMD fits of Drell-Yan data; numerical frameworks)

  e.g., Scimemi and Vladimirov: JHEP**06** 137 (2020)

  e.g., Camarda *et al.*, EPJC**80**, 251 (2020)

- lattice QCD calculations of TMDs

  e.g., Monahan, Del Debbio, Lin, Orginos; Snowmass LOI

- numerous other aspects/opportunities (<u>see</u>: this program)

  $\rightarrow$ <u>must coordinate for ultimate Snowmass studies!</u>