PDFs from an EIC perspective

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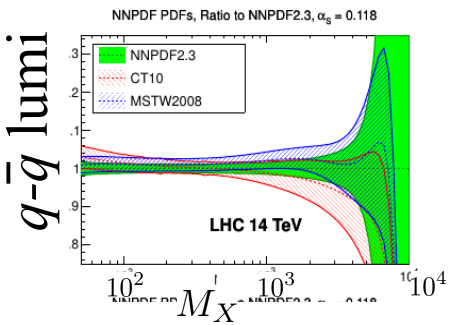
Joint CTEQ meeting / POETIC 7
Temple U., 16 November 2016

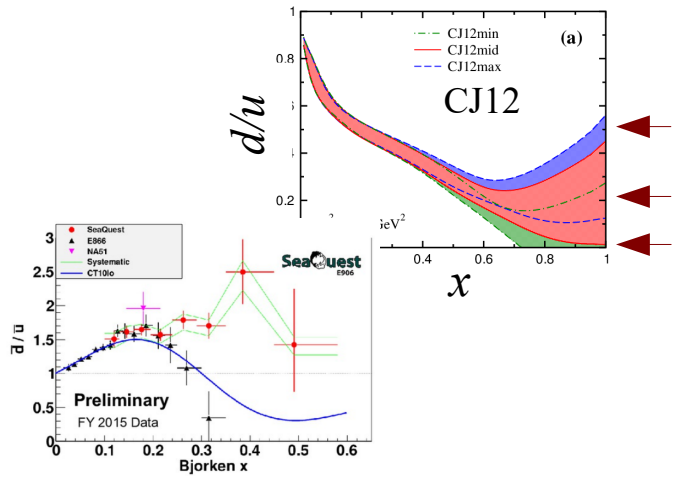
Why PDFs ?

Accardi – MPLA 28 (2013) 35 / PoS (DIS2015) 001
Forte and Watt – Ann.Rev.Nucl.Part.Sci. 63 (2013) 291

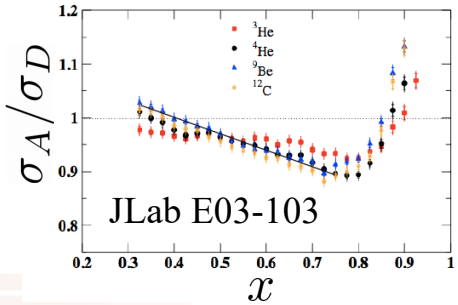
- **High-energy** *(large to small x)*
  - Beyond the Standard Model searches
  - Precision (Higgs) physics
  - NuTeV weak mixing angle
  - Gluonic "matter" at small *x*



- **Hadron structure** *(large to medium x)*
  - Effects of confinement on valence quarks
  - q – qbar asymmetries; isospin asymmetry
  - Strangeness, intrinsic charm



- **Nuclear Physics**
  - Bound nucleons, EMC effect, SRC
  - p+A and A+A collisions at RHIC / LHC
  - Color propagation in nuclear matter



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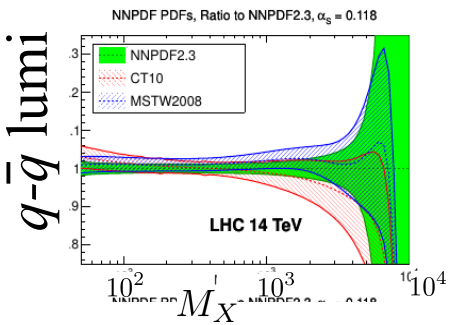

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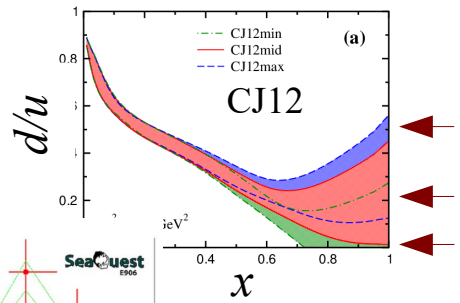

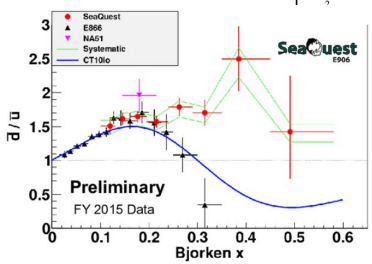

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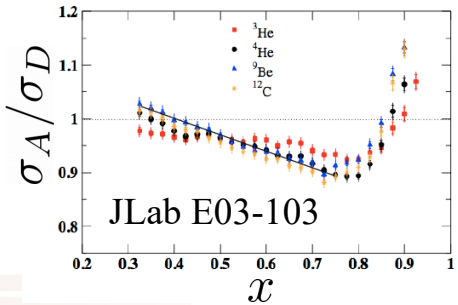
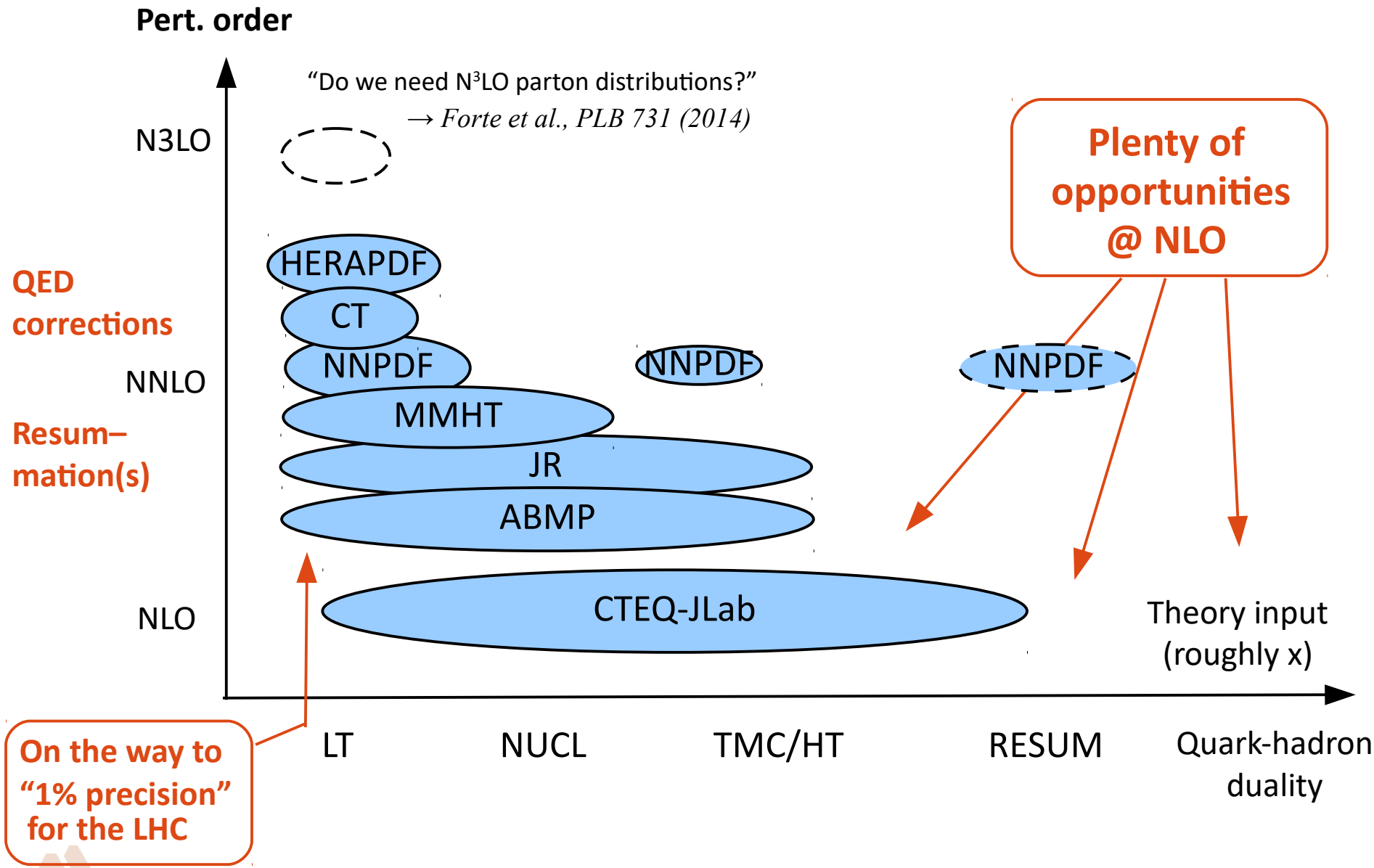
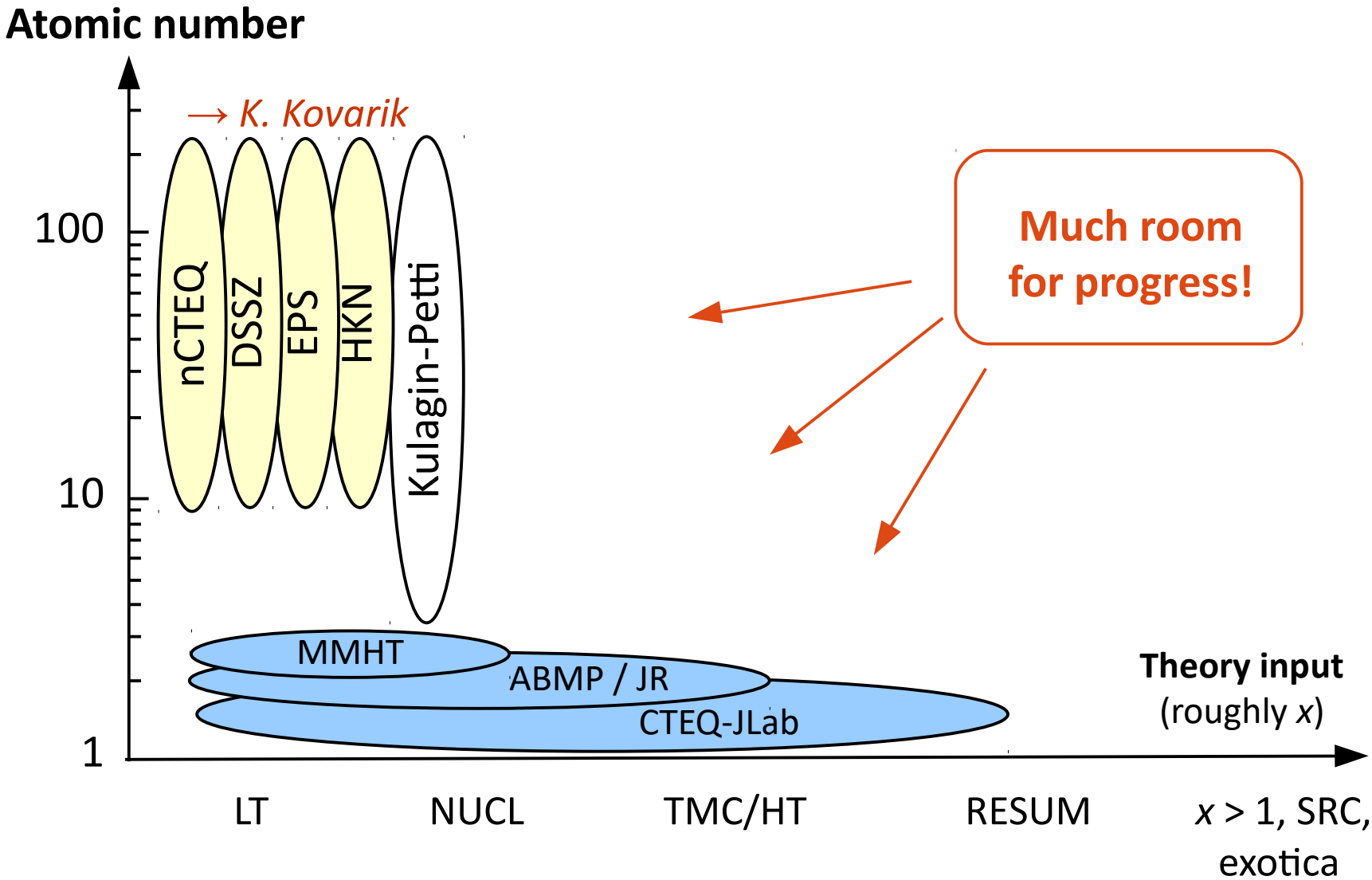


A PDF landscape

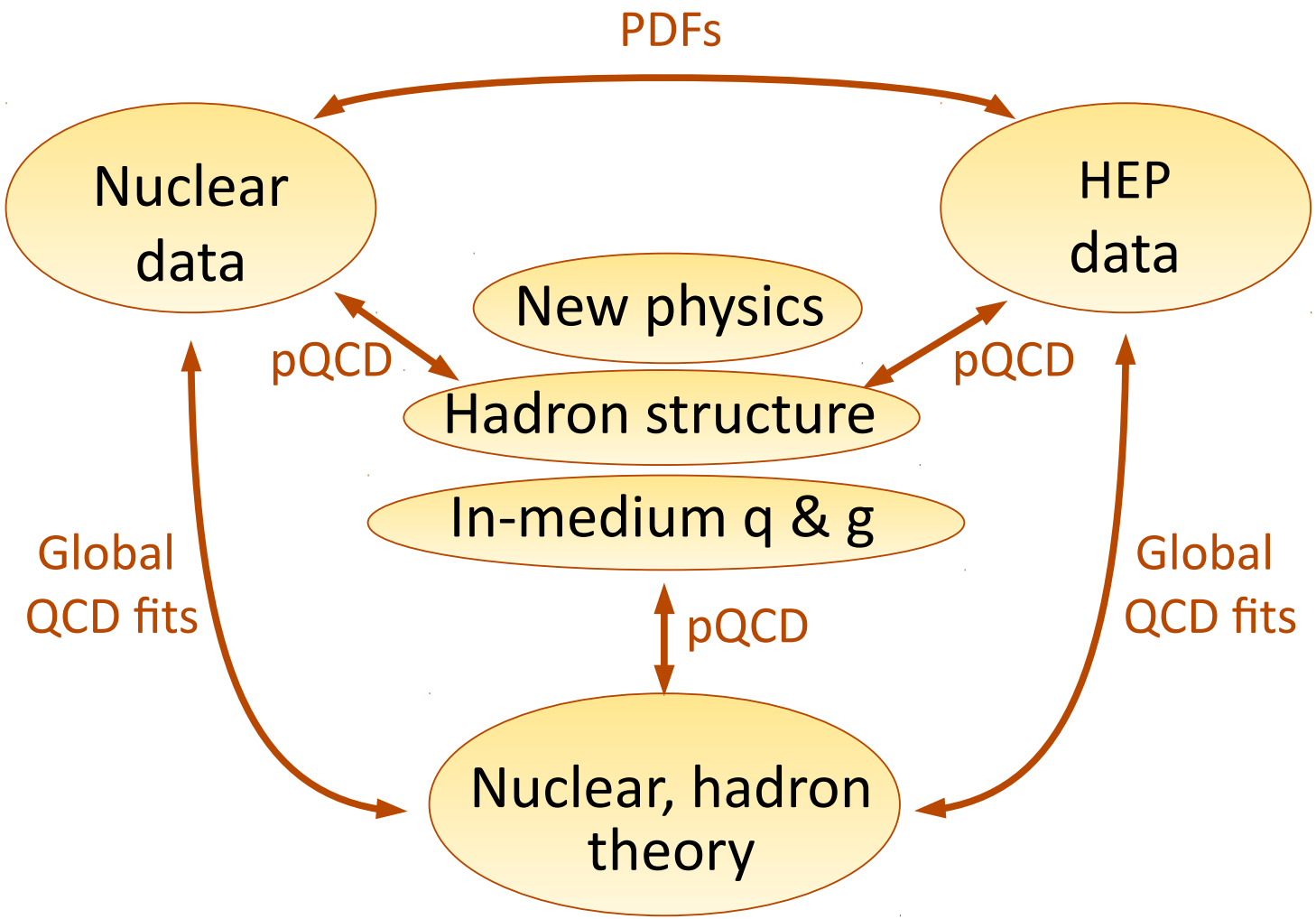


A nPDF landscape



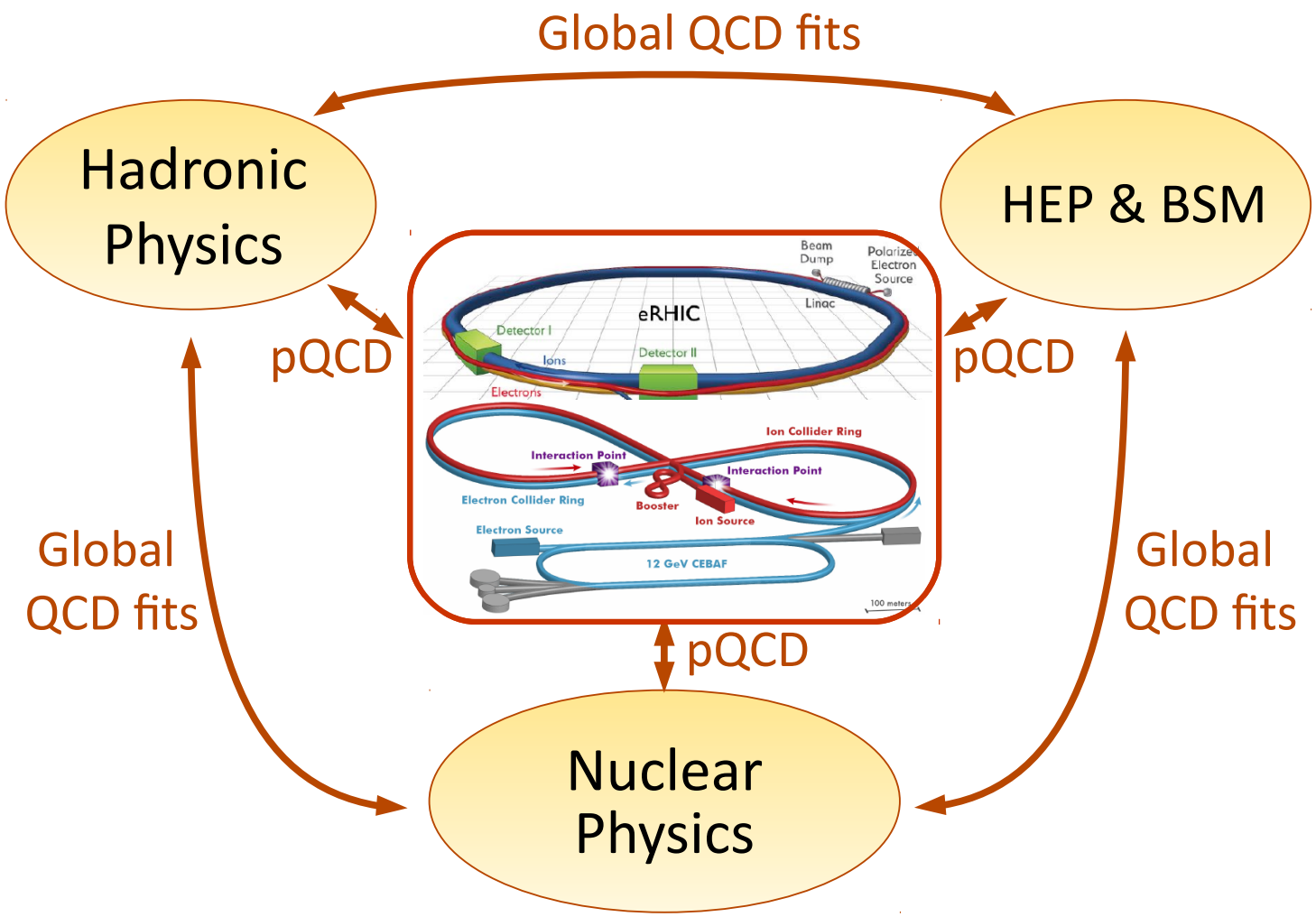
Needs the betrothal of HEP and NUCL

- **A global approach across subfields**



Enters the EIC

- **The EIC is the machine to bind them all**



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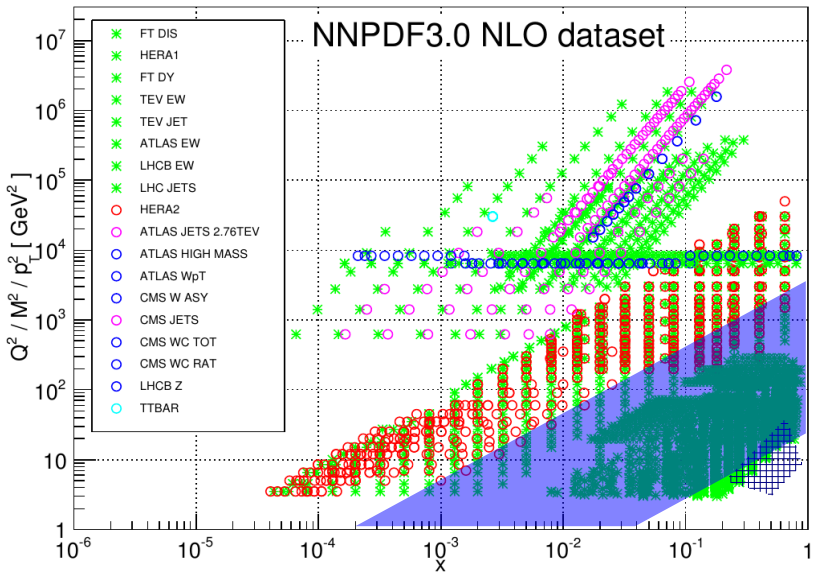


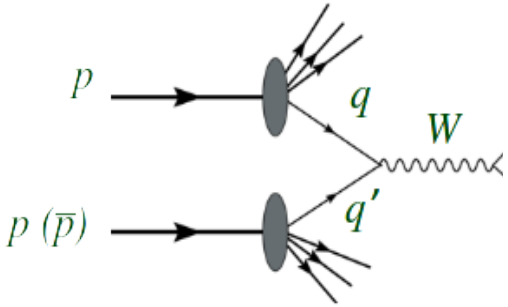
- Interpolates fixed target and HERA
- Large Q^2 leverage
  - More evolution at large x
  - Better separation of LT and HT
- High luminosity → large x capabilities

- **EIC can "do it all":**
  - "Easy" spectator tagging in DIS
  - Strong PID capabilities: → F_2^c, F_2^{cc}, Fragmentation Functions, ... → *N.Sato*
  - High luminosity → CC, PVDIS → d/u, strange quarks, dbar/ubar, ...
  - Unpolarized & polarized scattering (also light ions)
  - Nuclear targets → *K. Kovarik*

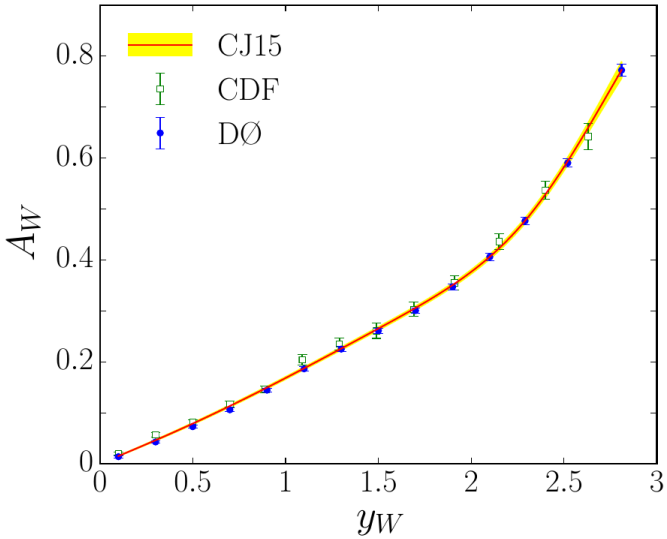
Example 1: Tevatron as NUCL facility (!)

Accardi, Brady, Melnitchouk, Owens, Sato, PRD93 (2016) 114017

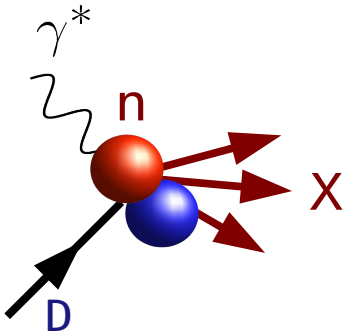
- ***Reconstructed W*** $\longrightarrow$ constrain *d*-quark at largest x on proton targets



$$A_W(y) \xrightarrow{x\to 1} \frac{1-d/u(x_1)}{1+d/u(x_1)}$$



- Compare to abundant deuteron ***DIS data:***
  - $\longrightarrow$ constrain deuteron corrections
  - $\longrightarrow$ precise *u*, *d* flavor separation



Example 1: Tevatron as NUCL facility (!)

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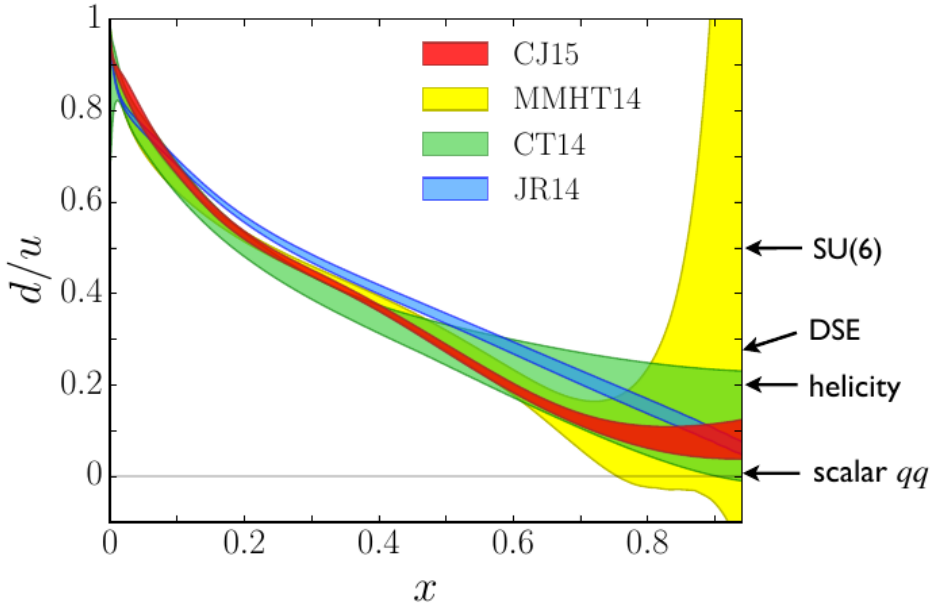
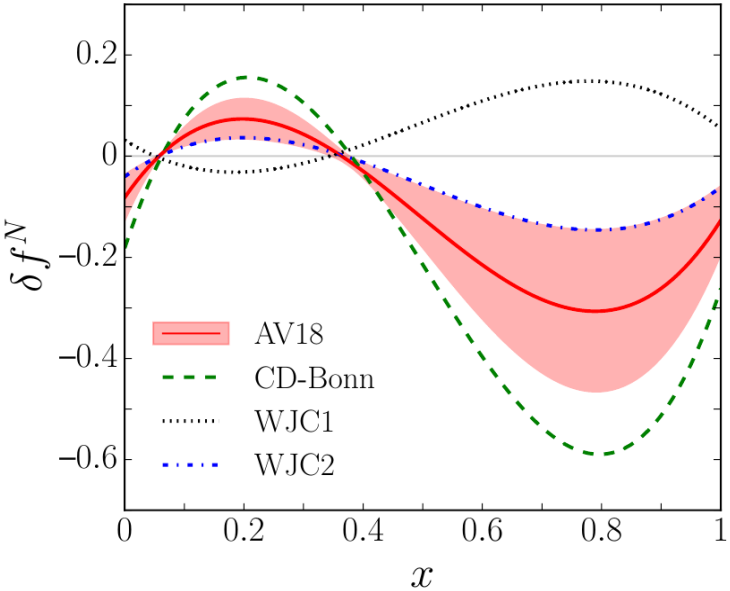
- **Two results in 1:**
  - → confinement at large x
  - → off-shell corrections in deuteron PDFs

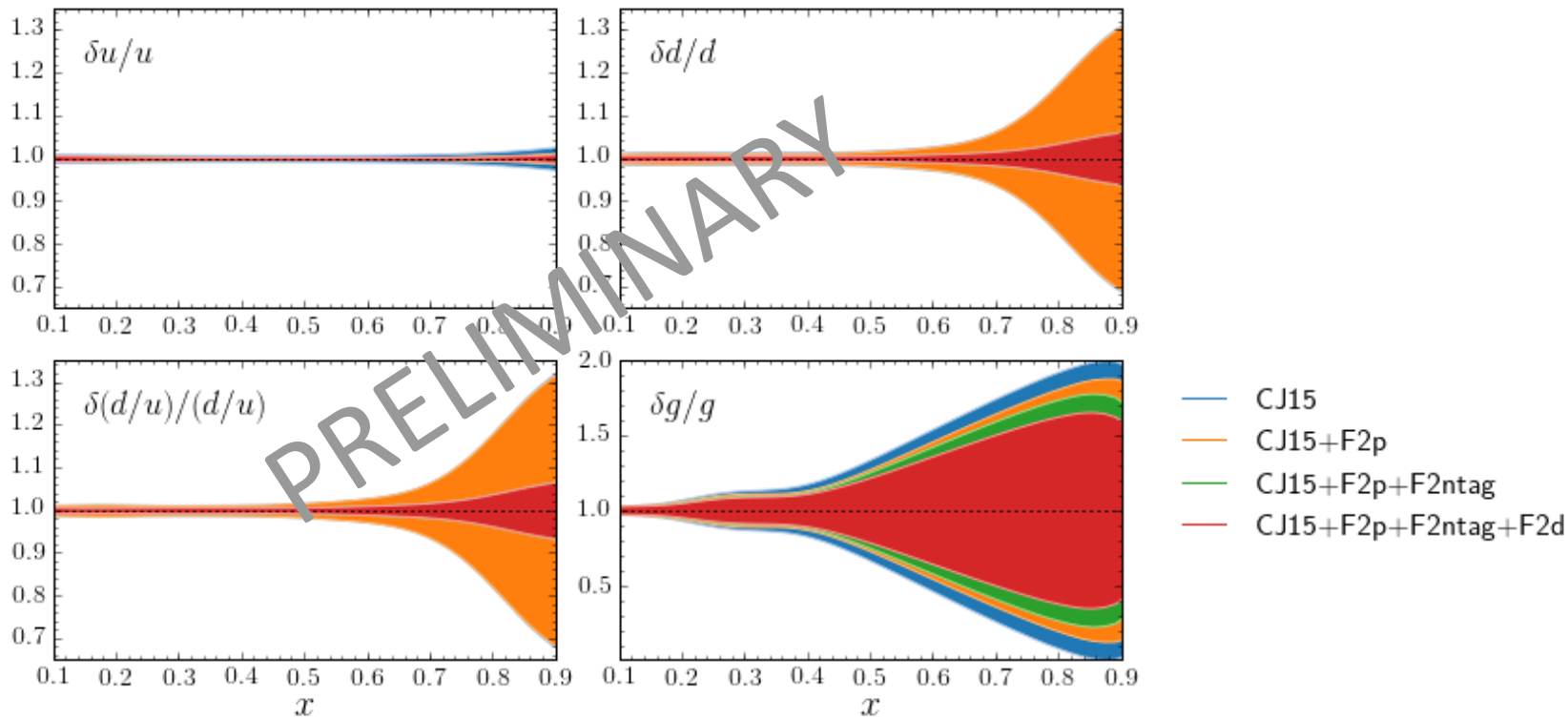




Example 2: large *x* PDFs at the EIC

Accardi, Ent, Keppel, Park, Yoshida – in progress

- Include **EIC projected data** in global fit:
  - L = 100/fb @ 10x100 GeV^2 energy
  - F2(proton), F2(deuteron), F2(tagged neutron) at 0.1 < x < 0.9



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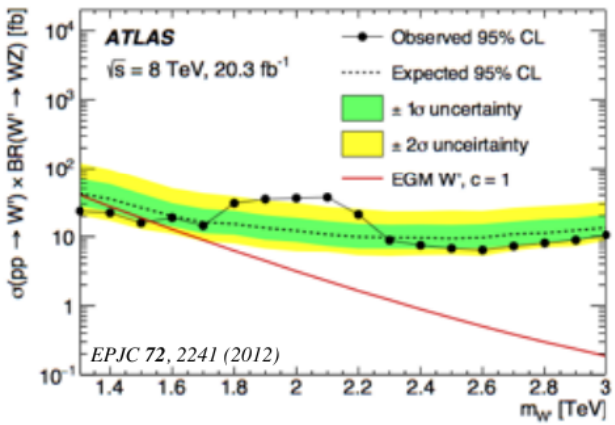
Accardi, Ent, Keppel, Park, Yoshida – in progress

- **Results**:
  - The ***d* quark precision will become comparable to current *u* !!**
  - The *u* quark uncertainty becomes less than 1%
  - 20% improvement in g(x) through evolution

- Can impact BSM searches, e.g., **heavy W' boson production at LHC**



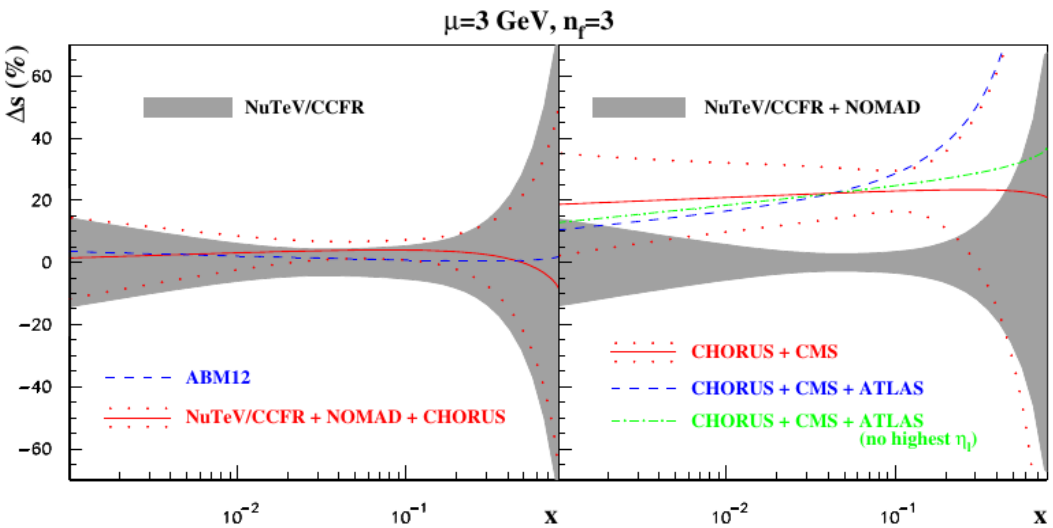
- $3.4\,\sigma$ excess in WZ diboson channel at ~ 2 TeV
- extended gauge model $W' \to WZ$ with $M < 1.5$ TeV excluded at 95% c.l.

$$\mathcal{L}_{W'} \to d(x_1)\,\bar{u}(x_2) \quad \text{at large } y_{W'} \text{ or } M_{W'}$$

$$x_{1,2} \approx \frac{M_{W'}}{\sqrt{s}} e^{\pm y_{W'}}$$

Example 3: strange, strange quarks

- **ν+*A* → dimuons** *vs.* ***p+p* → *W+c* at LHC** *Alekhin et al., arXiv:1404.6469*

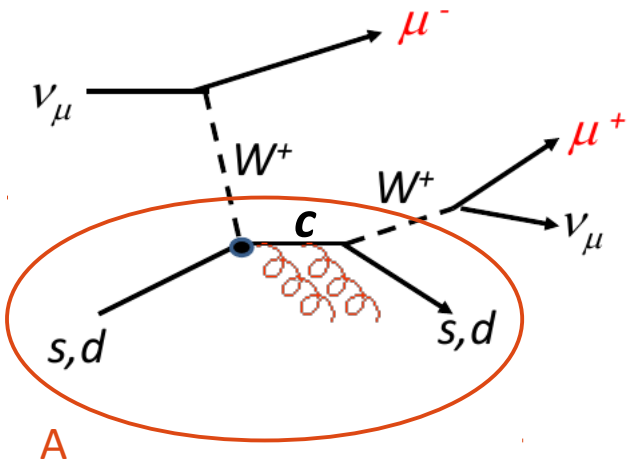


$$g\, s_p \to W\, c$$

FSI ?

$$\nu\, s_A \to \mu^-\, \mu^+\, \nu_\mu\, s$$

- **Final state propagation of *c* quark / D meson**
  - Not quite under theoretical or phenomenological control, yet (*cf.* heavy quark "puzzle" in A+A at RHIC, LHC)

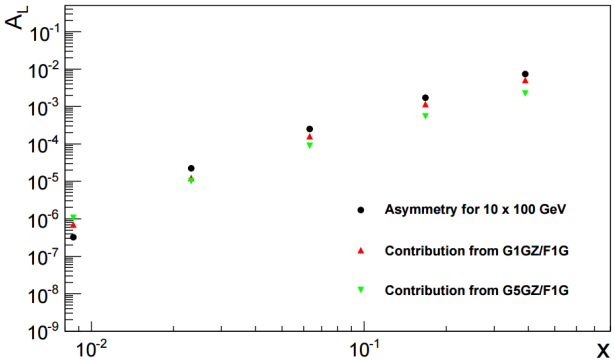


Example 3: strange, strange quarks

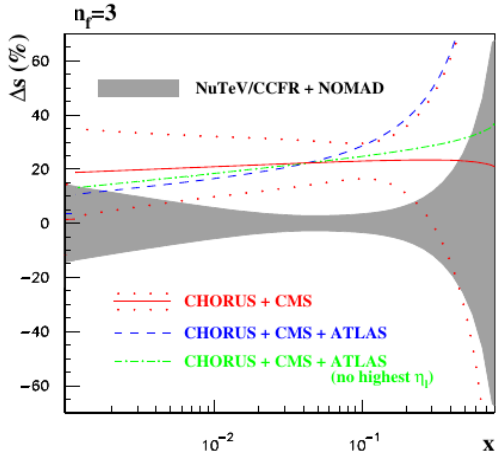
- Use **PVDIS projected data at EIC**

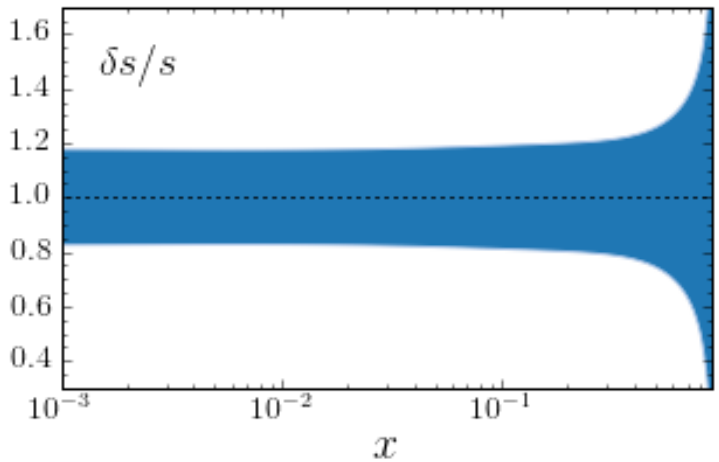
  → *Y. Zhao [Mon]*

$$A_L = \frac{G_F Q^2}{2\sqrt{2}\pi\alpha}\left[g_V^e \frac{g_5^{\gamma Z}}{F_1^\gamma} + g_A^e \frac{Y_-}{Y_+}\frac{g_1^{\gamma Z}}{F_1^\gamma}\right]$$



- Can constrain starnge at ~20% level, and
  - Help resolve LHC vs. ν+A tension (also with RHIC W&Z, PVDIS@JLab12)
  - Study charm propagation in nuclear matter



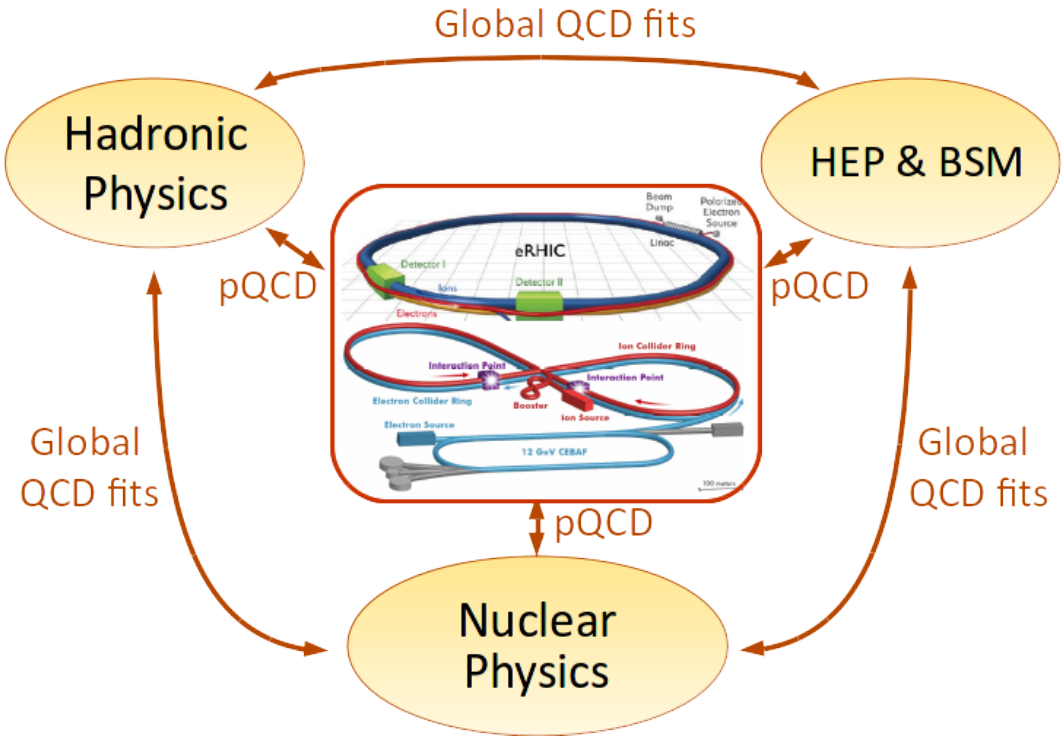


CJ15+EIC

15x250 GeV^2

Some final thoughts

EIC to bind them all



- EIC has excellent potential, for example, for
  - **u, d, g flavor determination at large x** ⟷ hadronic structure, BSM
  - **Strangeness** in complementary x range to LHC, similar to RHIC
  - **Revolutionizing nuclear physics studies using hard probes**

What else can we dream of doing at the EIC?

- **Isospin violations**
  - Play free n from BONUS/EIC vs. free p from D0, RHIC W-asym.
- **Intrinsics charm**
  - Positive signal only from (contested) EMC data
  - Take new and better data with EIC !
- **Large leverage in A – from light to heavy**
  - Combined PDF / nPDF fits → *K. Kovarik (?)*
  - Structure of light nuclei, by contrast with heavy & p, d
- **Polarized and unpolarized data at large Q2 from same machine**
  - Another combined fit ⟷ helicity separation
- **SIDIS & DIS (at large Q2) from same machine** → *N.Sato*
  - Will reduce many uncertainties
  - Yet another combined fit ⟷ flavor separation
- ...