Future Facilities and Experiments

Summary

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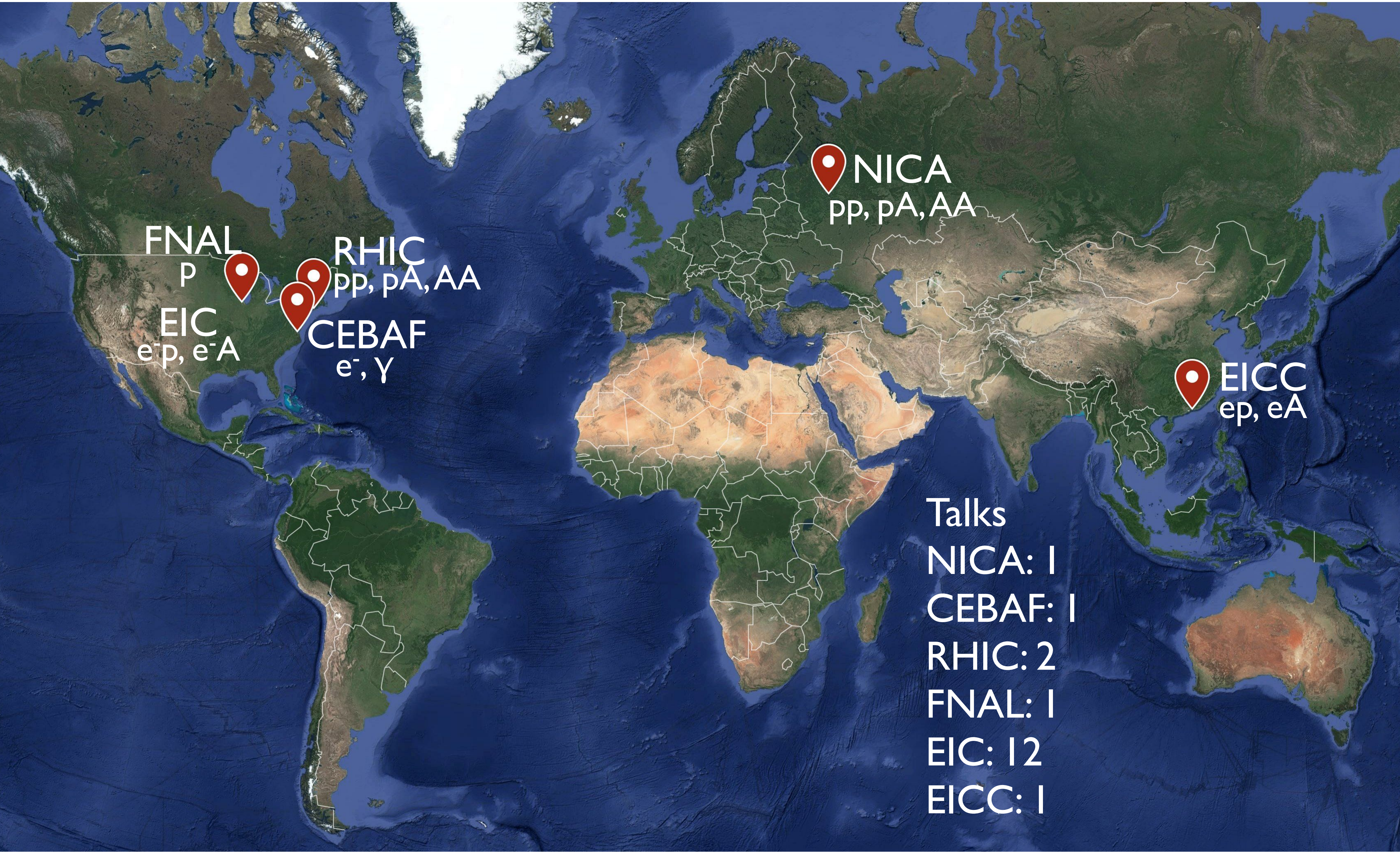
Spin 2018

23RD INTERNATIONAL SPIN SYMPOSIUM

FERRARA - ITALY

10 - 14 SEPTEMBER 2018

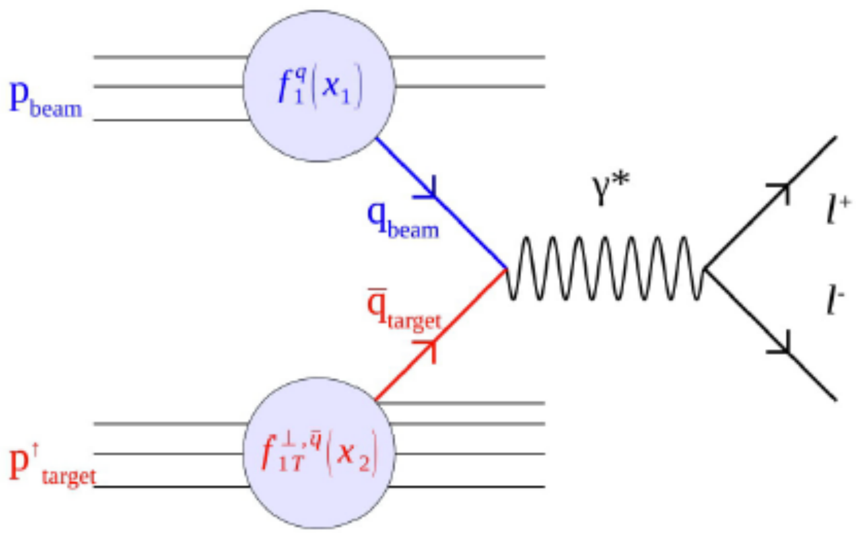
Facilities Landscape



Polarized Drell-Yan at Fermi Lab

Andrew Chen

Polarized Drell-Yan

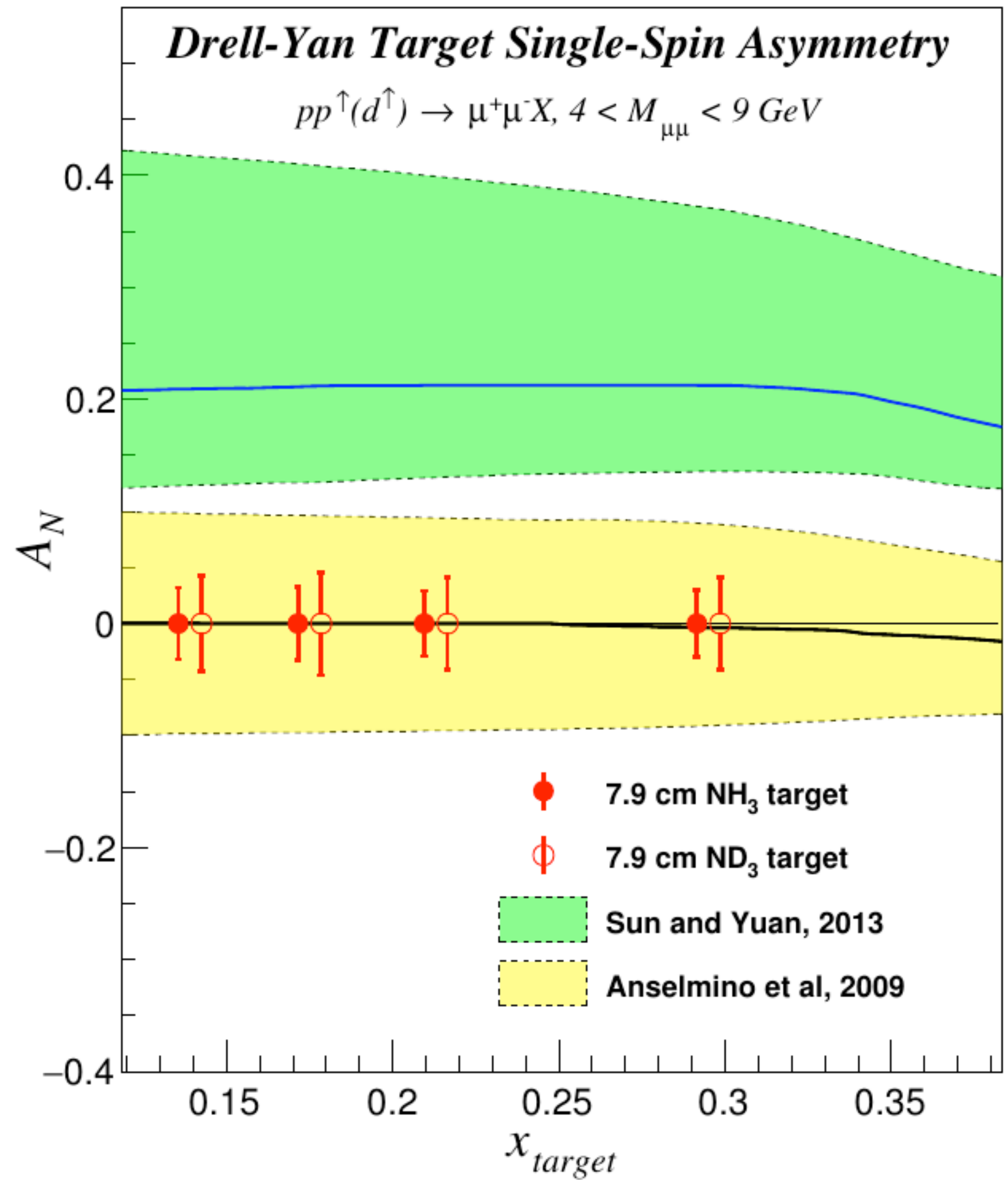


E1039 Seaquest Experiment

$$A_N^{DY} \propto \frac{\sum_q e_q^2 [f_1^q(x_1) \cdot f_{1T}^{\perp,\bar{q}}(x_2) + 1 \leftrightarrow 2]}{\sum_q e_q^2 [f_1^q(x_1) \cdot f_1^{\bar{q}}(x_2) + 1 \leftrightarrow 2]}$$

A fixed target Drell-Yan Experiment with polarized target isolates sea quark Sivers TMD to target!

Proton beam on NH_3, ND_3 polarized targets
Measurements of A_N, A_Q (tensor charge)

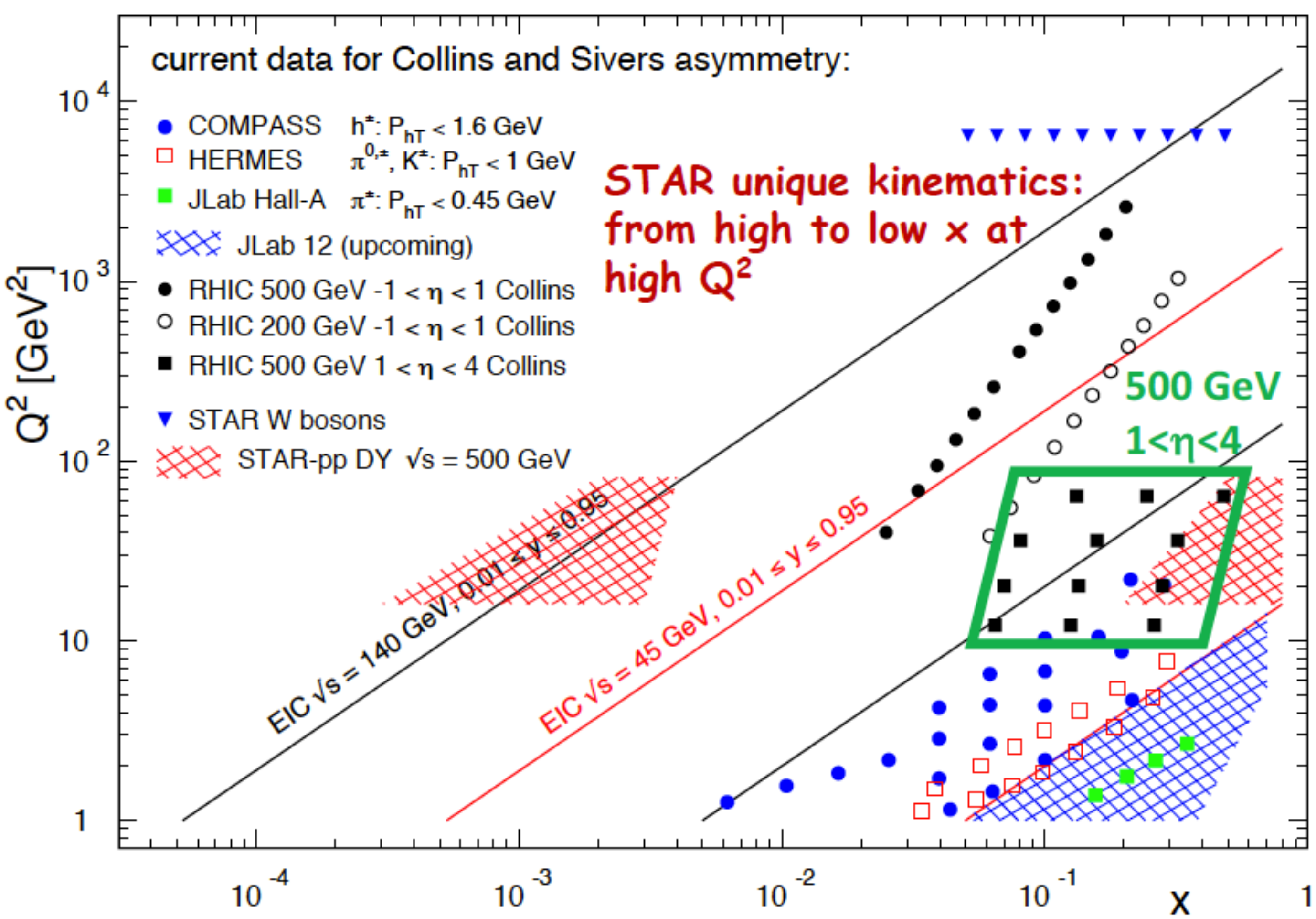


STAR Forward Rapidity Upgrade

Kenneth Barish

Forward Instrumentation for STAR Upgrade (I)

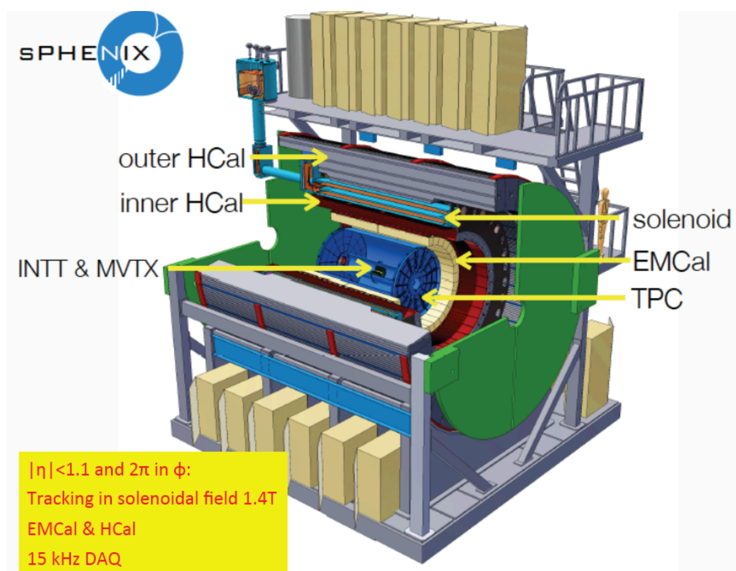
Detector	pp and pA	AA
ECal	~10%/√E	~20%/√E
HCal	~60%/√E	---
Tracking	charge separation photon suppression	$0.2<p_T<2$ GeV/c with 20-30% $1/p_T$

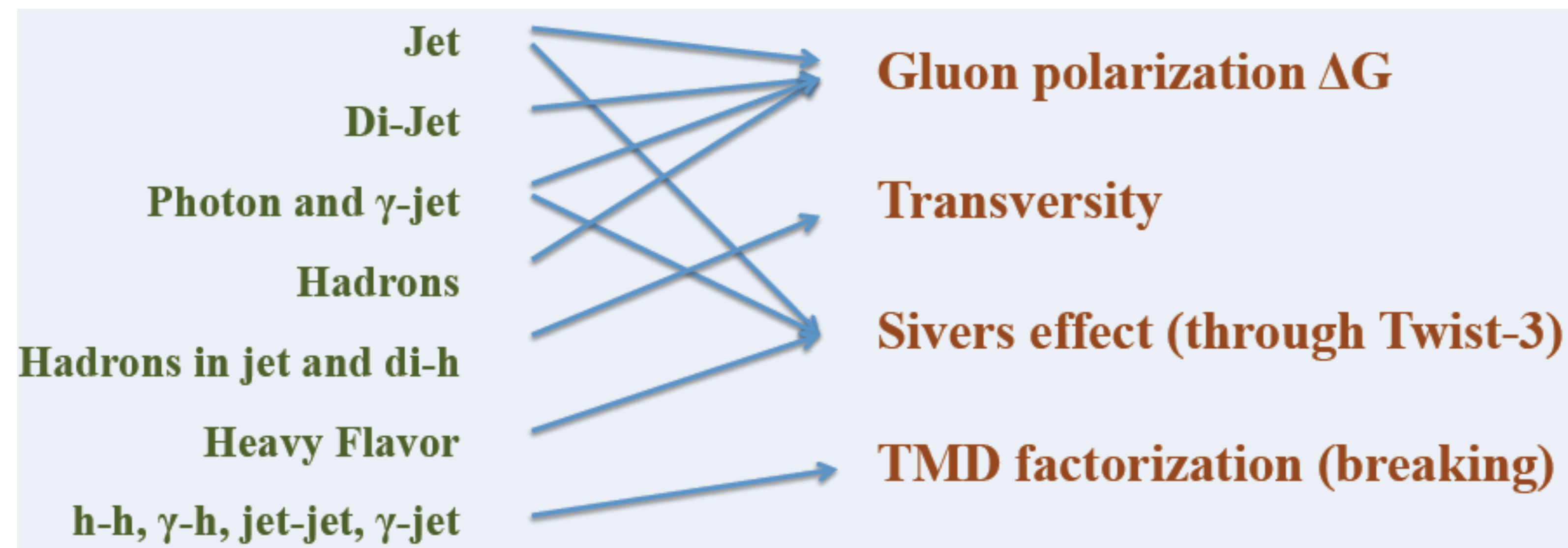


- Comprehensive TMD physics
- Gluon polarization
- pA physics
  - nuclear PDFs (gluon PDFs, sea quark PDFs)
  - final-state effects
  - saturation (di-hadron correlations, forward γ+jet)

Spin Physics with sPHENIX

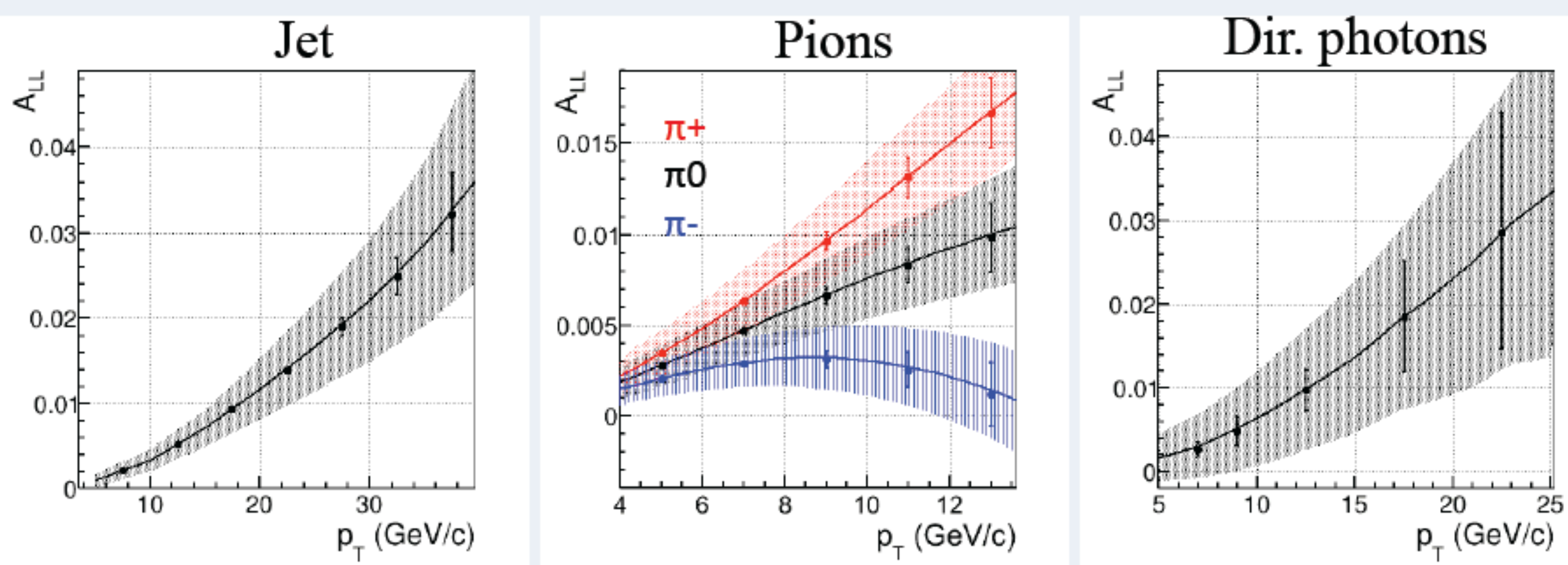
Alexander Bazylevsky





ΔG projection

$\sqrt{s}$=200 GeV |η|<1.1
L=700 pb^{-1} P=0.6
Theory curve and band: NNPDF



High-precision ΔG measurements (at x> 0.05, ΔGdx-integral precision improvement by a factor of 4

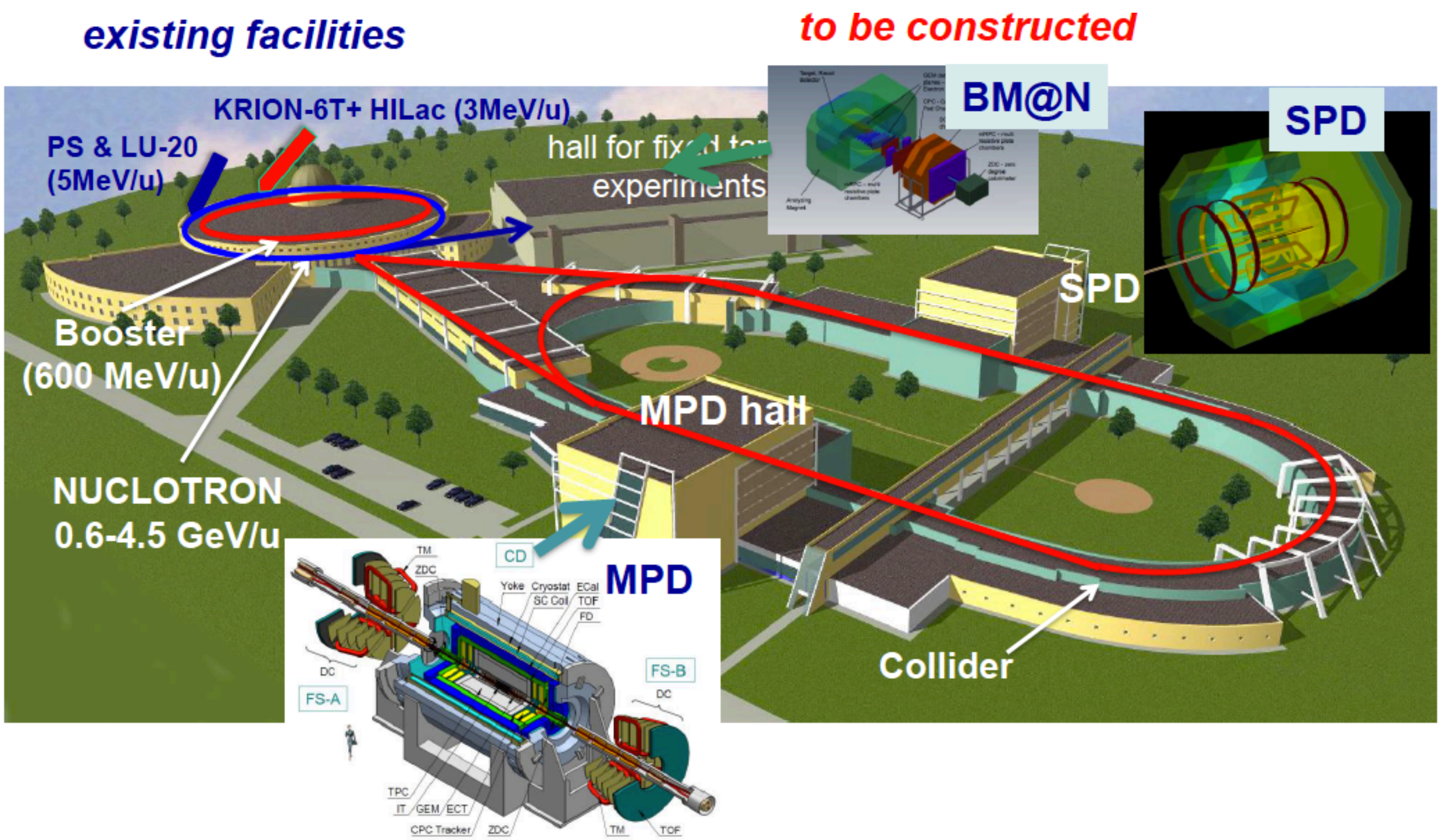
Multiple channels

Complementary to future EIC

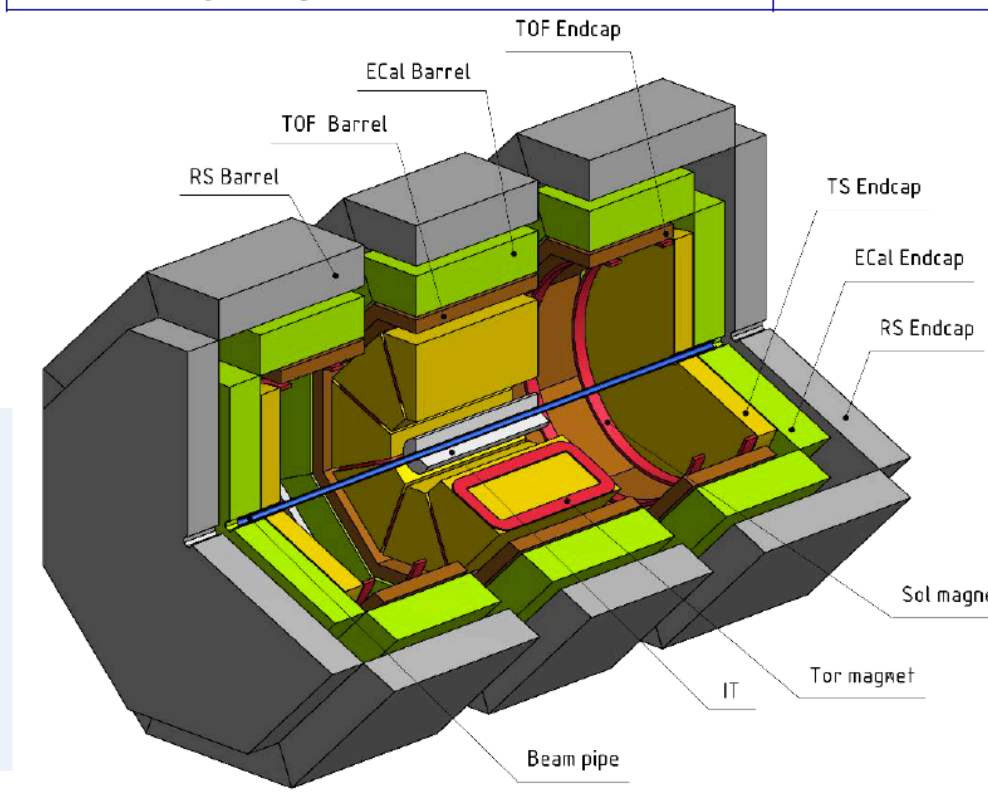
The SPD Project at NICA

Roumen Tsenov

The Nuclotron based Ion Collider fAcility (JINR, Dubna)



Ring circumference, m	**503.04**
heavy ions	
energy range for ***Au***$^{79+}$*:* $\sqrt{S_{NN}}$*, GeV*	**4 - 11**
r.m.s. $\Delta p/p$*,* 10^{-3}	**1.6**
Luminosity for ***Au***$^{79+}$*,* $cm^{-2}\ s^{-1}$	1×10^{27}
polarized particles	
max. $\sqrt{S}$ *for polarized* ***p****, Gev*	**27**
Luminosity for ***p****,* $cm^{-2}\ s^{-1}$	1×10^{32}

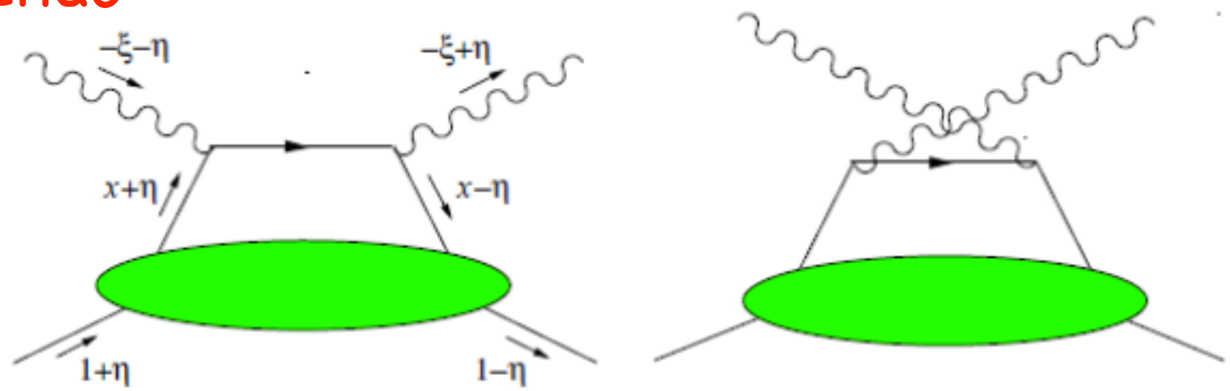


Physics Highlight: Nucleon Spin Structure

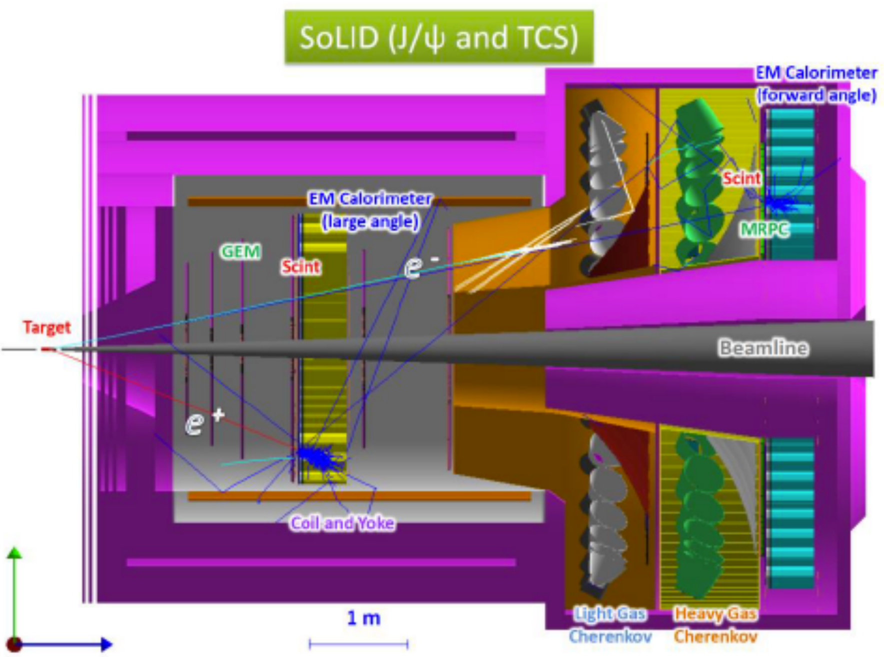
- Drell-Yan Production
- Direct Photons
- Nucleon PDFs via J/ψ Production

3D Nucleon Structire with the Solenoidal Large Intensity Device (SoLID) at JLab

Zhiwen Zhao



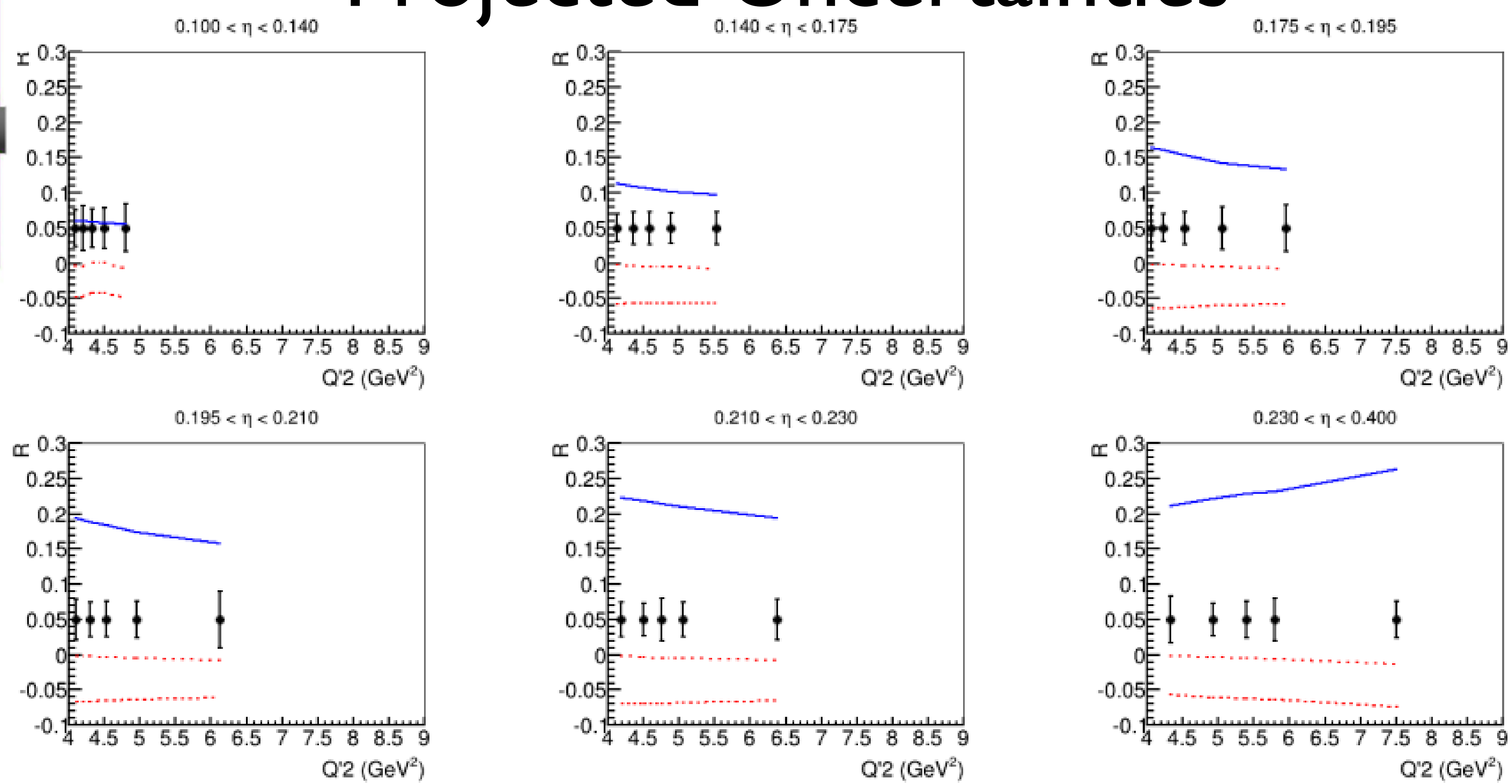
DVCS $(\gamma' \rightarrow \gamma)$
TCS $(\gamma \rightarrow \gamma')$
DDVCS $(\gamma' \rightarrow \gamma')$



Lumi ~1e^{37}/cm^2/s (open geometry)

- 3D hadron structure
  - TMD (SIDIS on both neutron an proton)
  - GPD (TCS, DEMP)
- Gluon and nucleon mass
  - J/ψ production at threshold

Projected Uncertainties



The U.S. Electron-Ion Collider

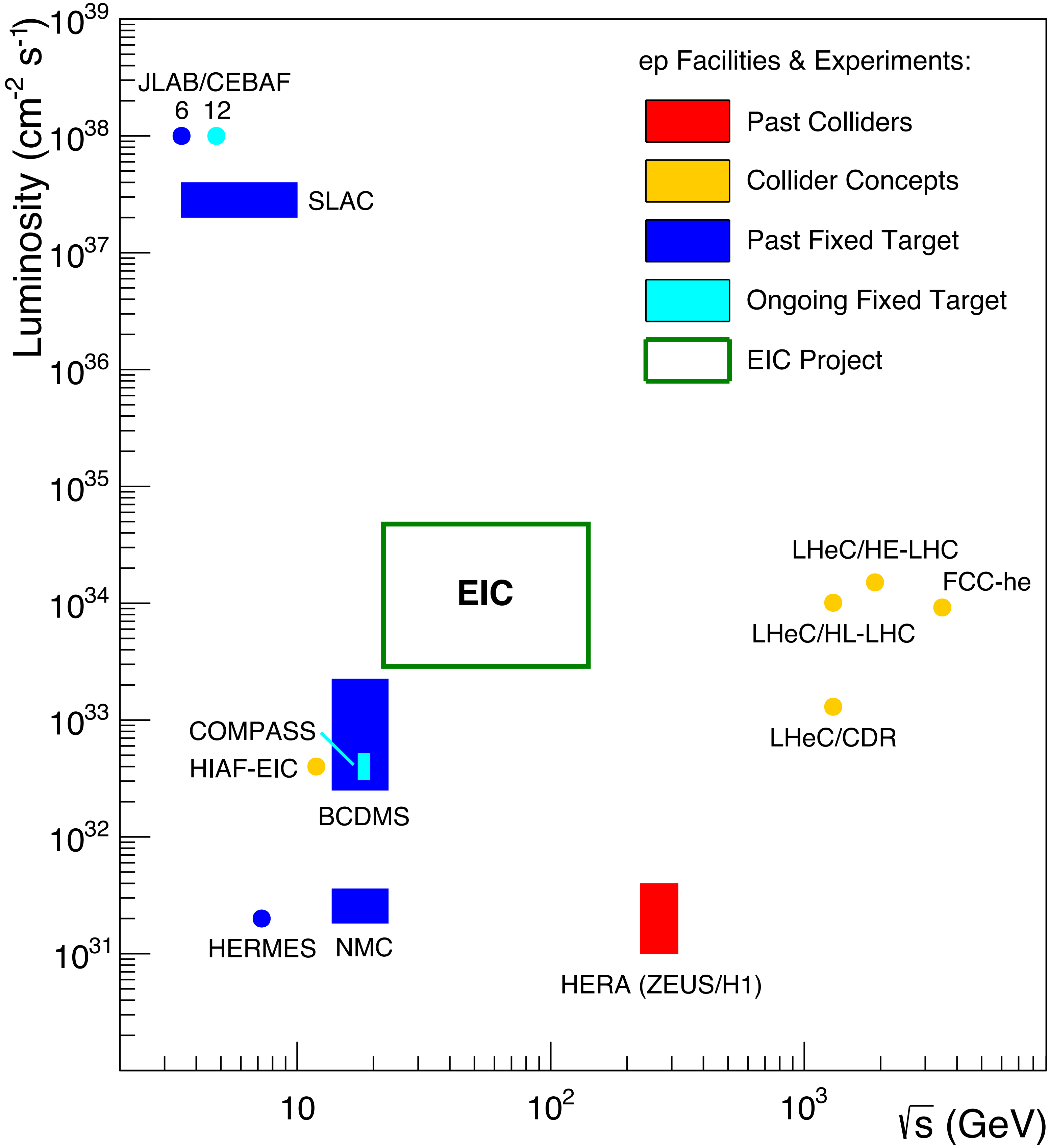
National Academy of Sciences Review of Science Merit (2018)

An EIC can uniquely address three profound questions about nucleons—neutrons and protons—and how they are assembled to form the nuclei of atoms:

- *How does the* ***mass*** *of the* ***nucleon*** *arise?*
- *How does the* ***spin*** *of the* ***nucleon*** *arise?*
- *What are the emergent properties of* ***dense systems of gluons****?*

Unique Features

- polarized electron, proton, and light ion beams (>70%)
- $L=10^{33-34}$ $cm^{-2}s^{-1}$ (ep)
- variable CM energy: 20-100 (140) GeV

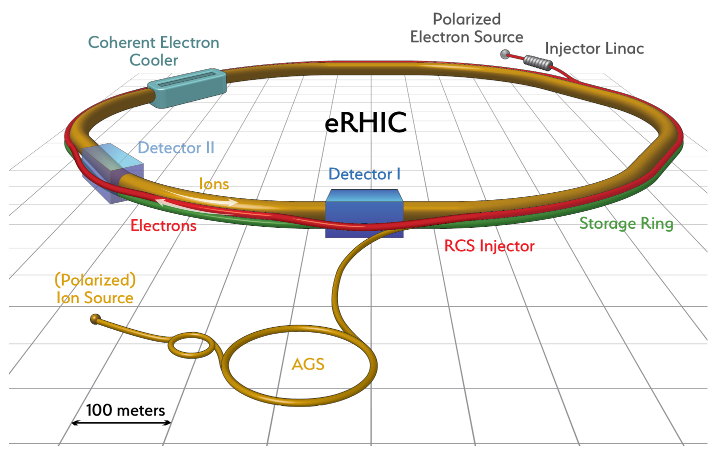


Electron-Ion Collider Designs

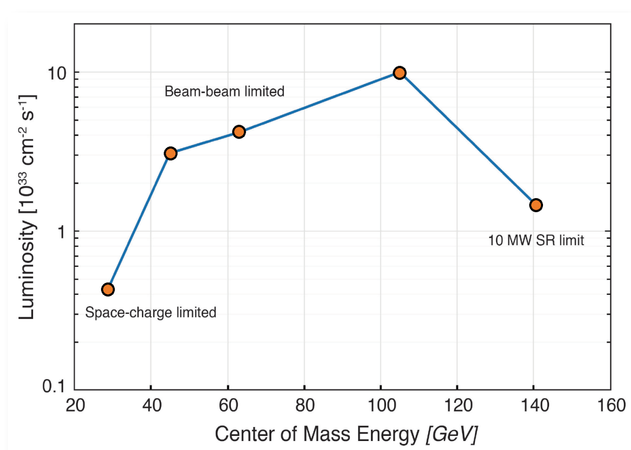
Joined R&D programs (cooling, Interaction Region design, backgrounds)
Both labs are working on design optimizations

eRHIC

Christoph Montag

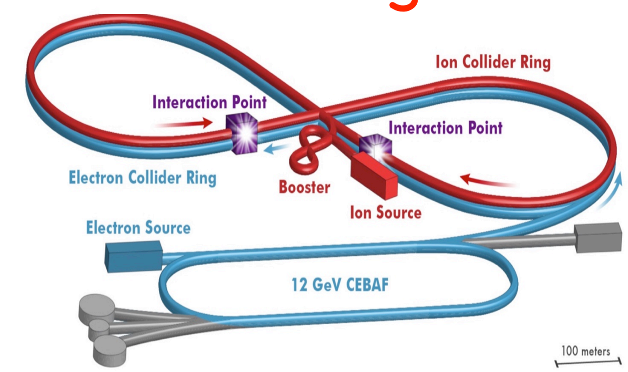


Exploring existing Hadron complex RHIC
p:275 GeV
Adding an electron accelerator
e: 5-18 GeV
$\sqrt{s}$ ~ 29-141 GeV
L~ $1{\cdot}10^{34}$ $cm^{-2}s^{-1}$



JLEIC

Fanglei Lin



Exploring existing Electron complex CEBAF
e: 3-12 GeV
Adding Ion complex
p: 20-100(400) GeV
$\sqrt{s}$ ~ 20-65 (140) GeV
L~ $4{\cdot}10^{34}$ $cm^{-2}s^{-1}$

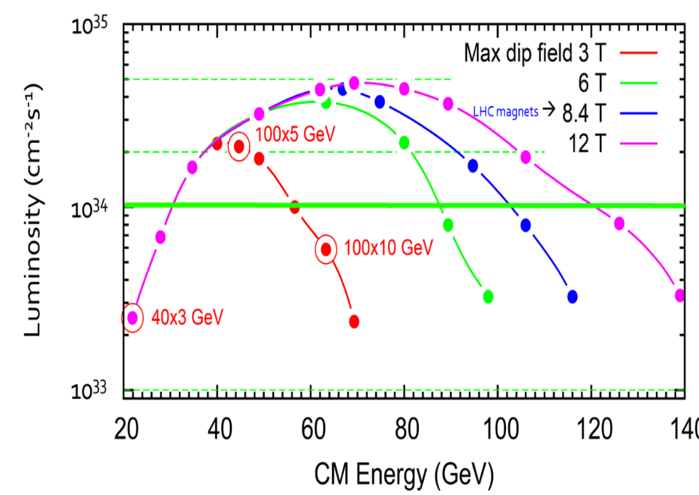


Figure-8: High polarization (~80%)

- ✓ Wide range of nuclear beams D to U,
- ✓ High beam polarizations for hadrons and electrons
- ✓ Integration of detector and IR

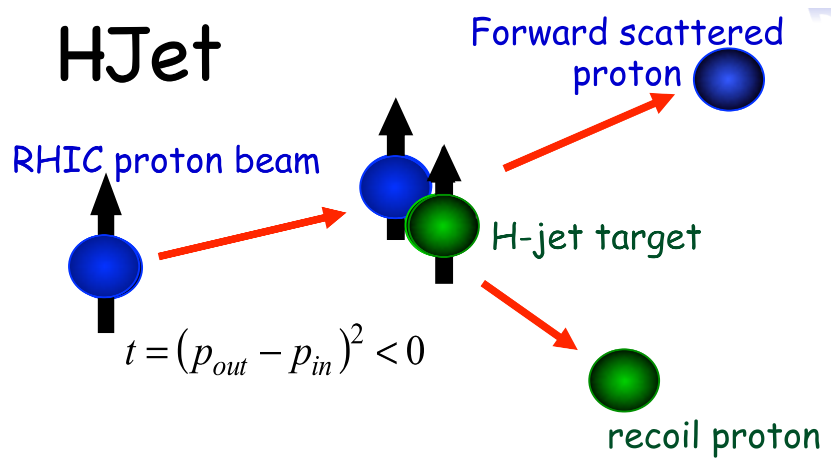
Hadron-Beam Polarimetry at Colliders

Haixin Huang

Polarized Hydrogen Jet Polarimeter (HJet): absolute polarization, but slow

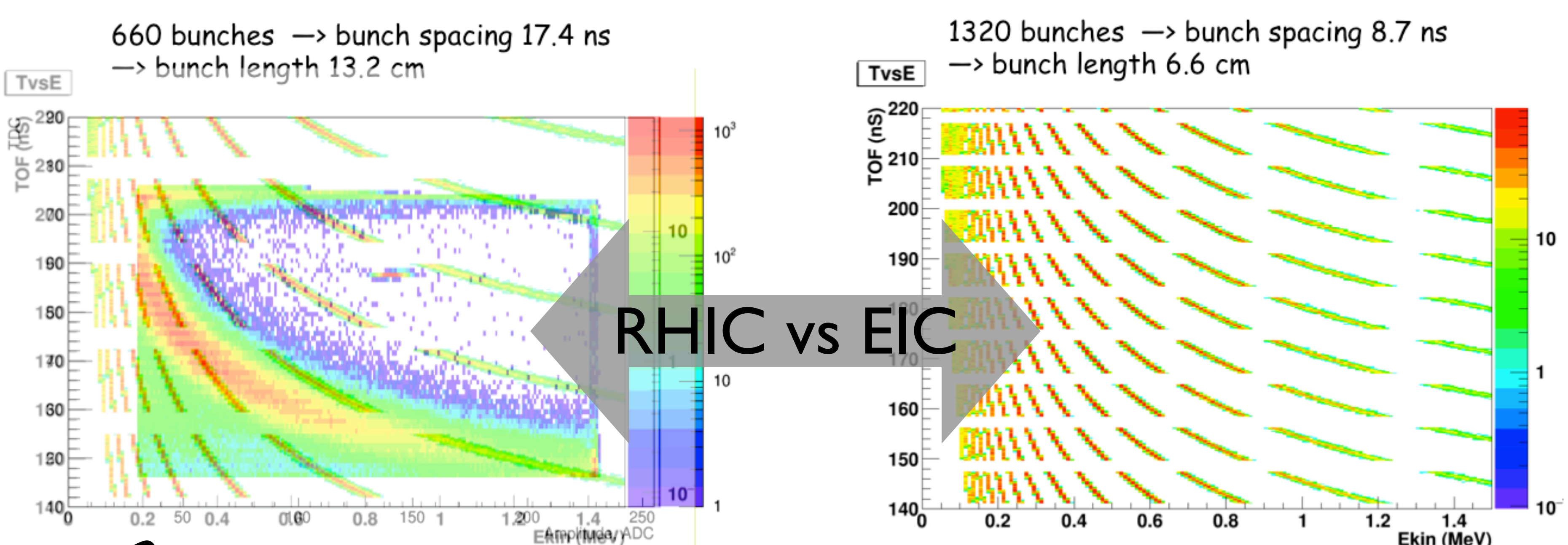
Proton Carbon Polarimeter (pC): very fast and high precision, measures polarization profile and lifetime, but needs to be normalized to HJet

HJet



$$P_{beam} = P_{target} \frac{\varepsilon_{beam}}{\varepsilon_{target}}$$

ε : measured left/right asymmetry



pC

EIC Challenges

- increased bunch frequency and number→lose data with highest stat. and analyzing power
- background effect

Mitigations

Spin Physics at EIC

Daniel Boer

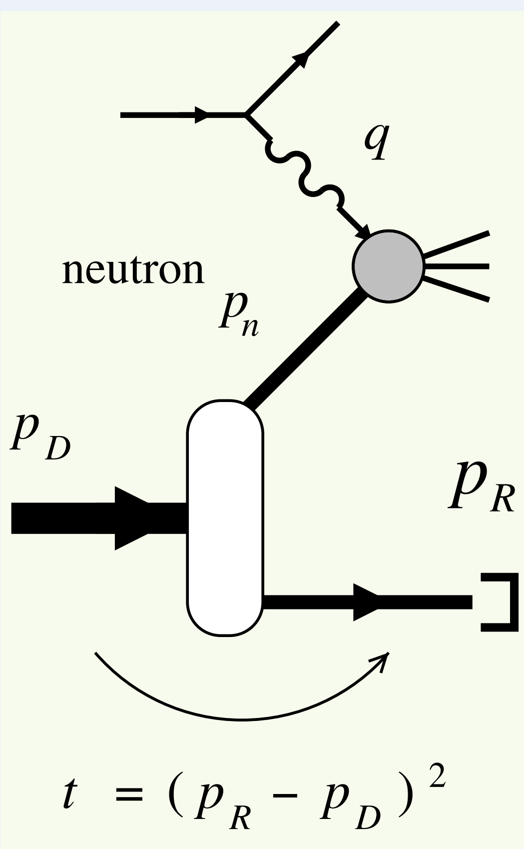
- Electroweak Structure Functions, quark and gluon TMDs, GTMDs, and GPDs
- Polarized deuteron
- Specific spin effects probed with particular final states
  - Heavy Quarks: gluon TMDs
  - Λs and di-hadrons: polarization dependent fragmentation functions
- Synergy and interplay with results from pp and e^+e^- collisions

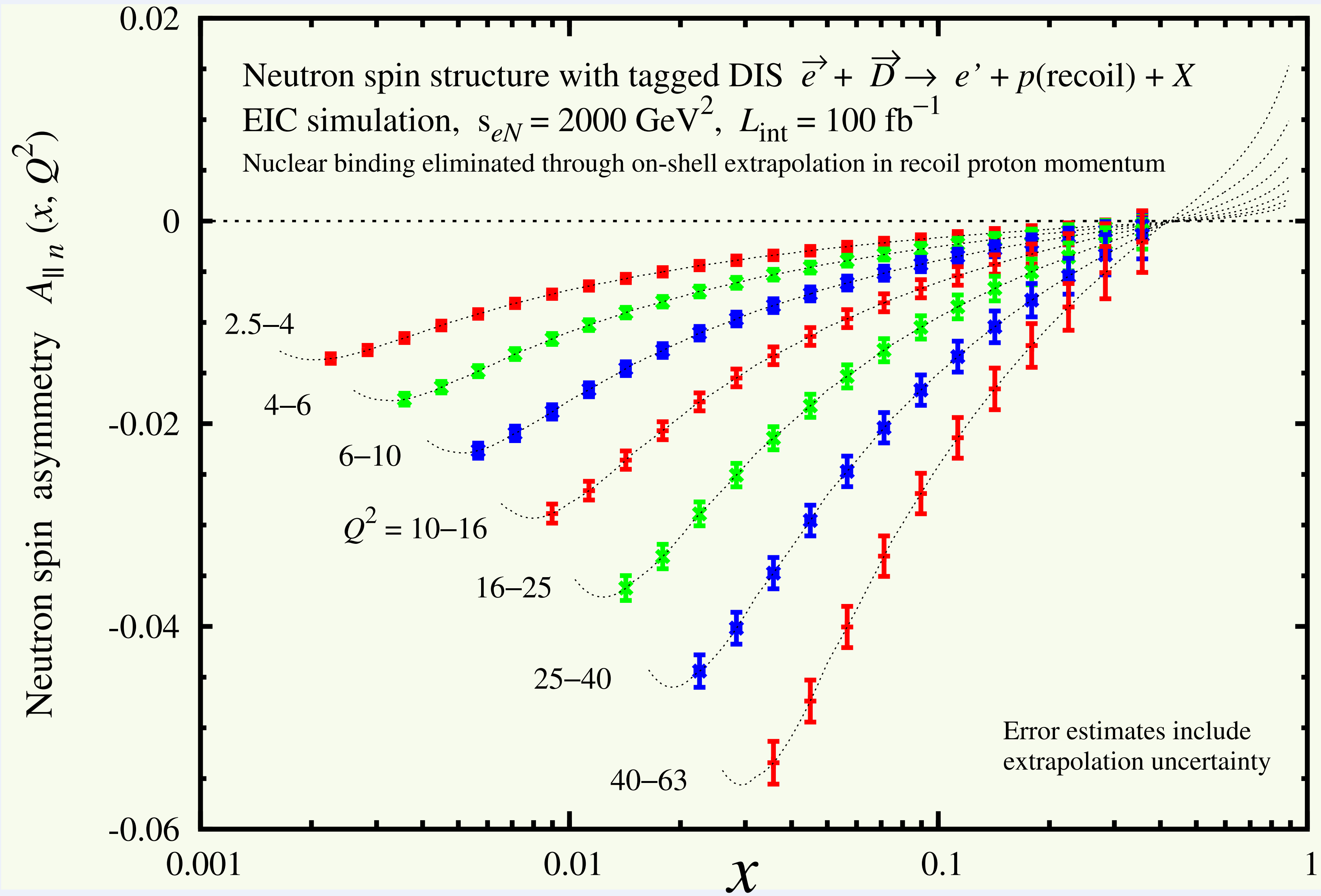
Spin Physics at EIC

Wim Cosyn

Physics with Light Ions (neutron structure, nucleon interactions in QCD, imaging nuclear bound states)

Neutron Structure with Spectator Tagging





Spin Physics at EIC

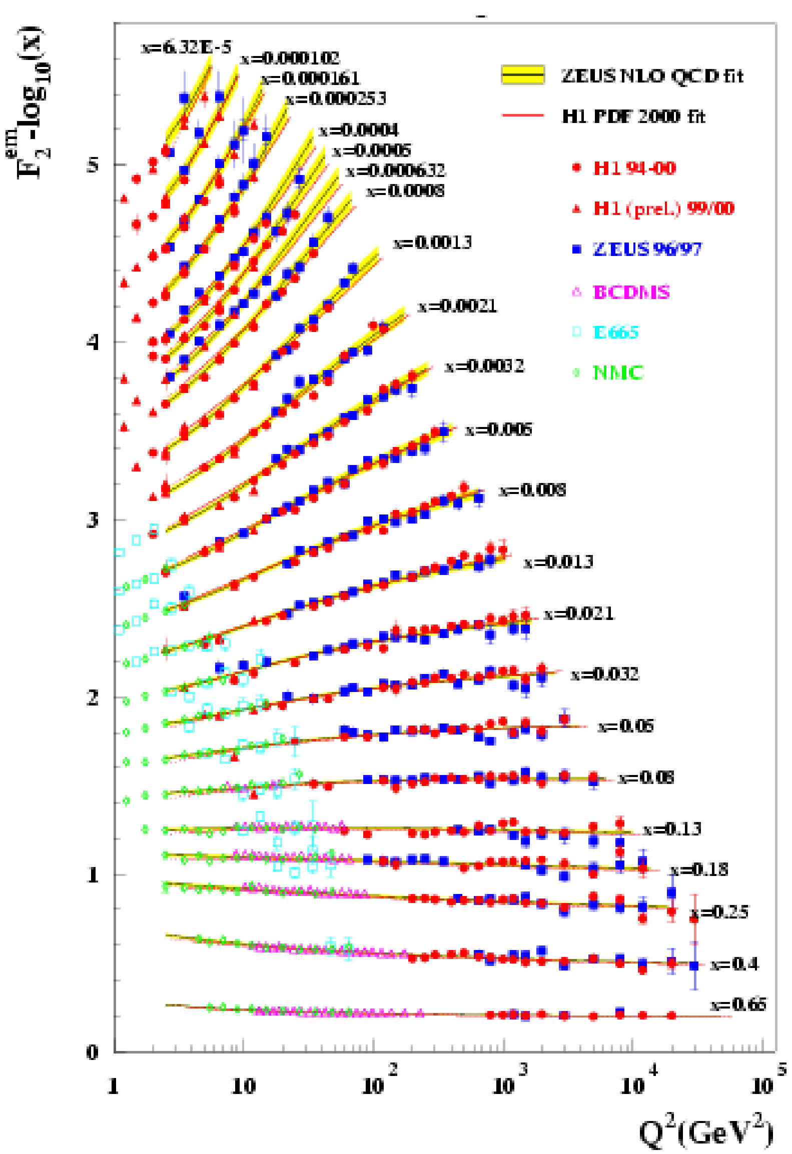
Rick Yoshida

World Data on F_2^p — World Data on g_1^p — World Data on h_1^p

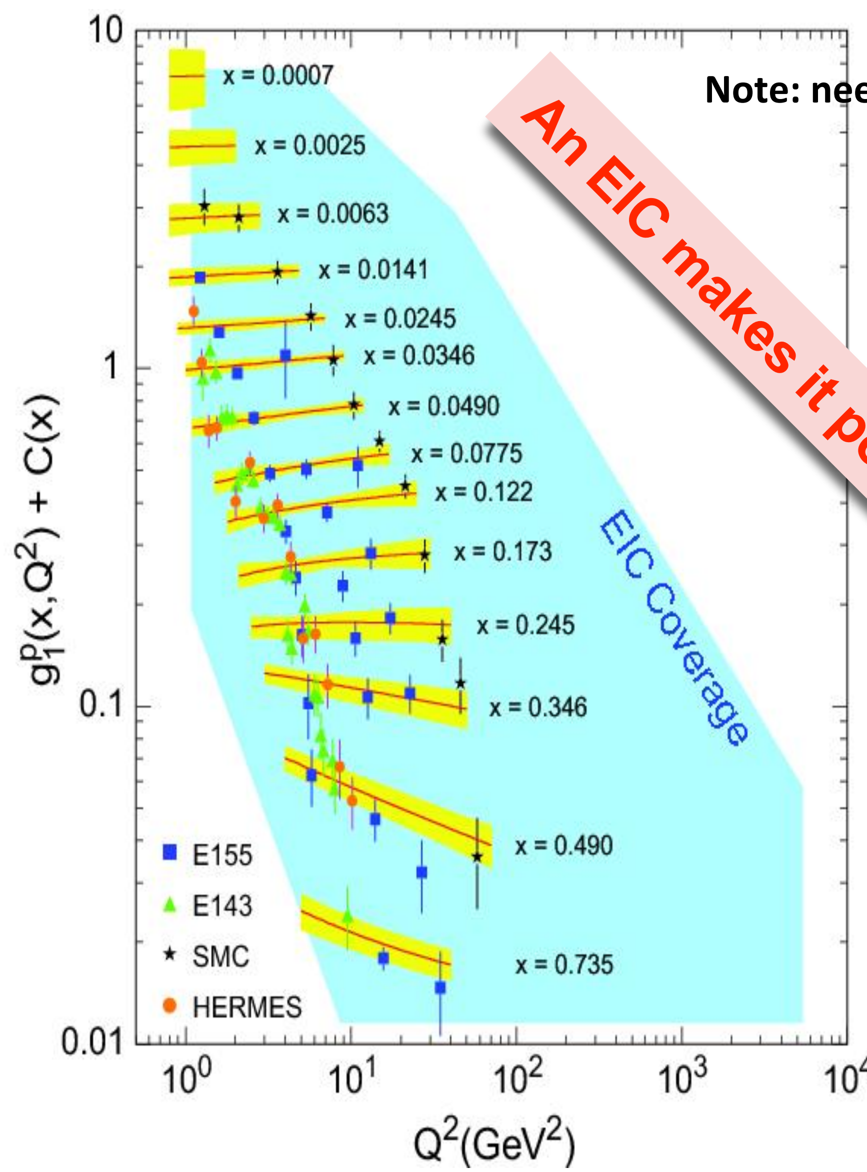
Similar for F_2^n

Similar for g_2^p, g_2^n (and b_1^d)

$F_{UT}^{\sin(\phi_h+\phi_S)}(x,Q^2) + C(x) \propto h1$



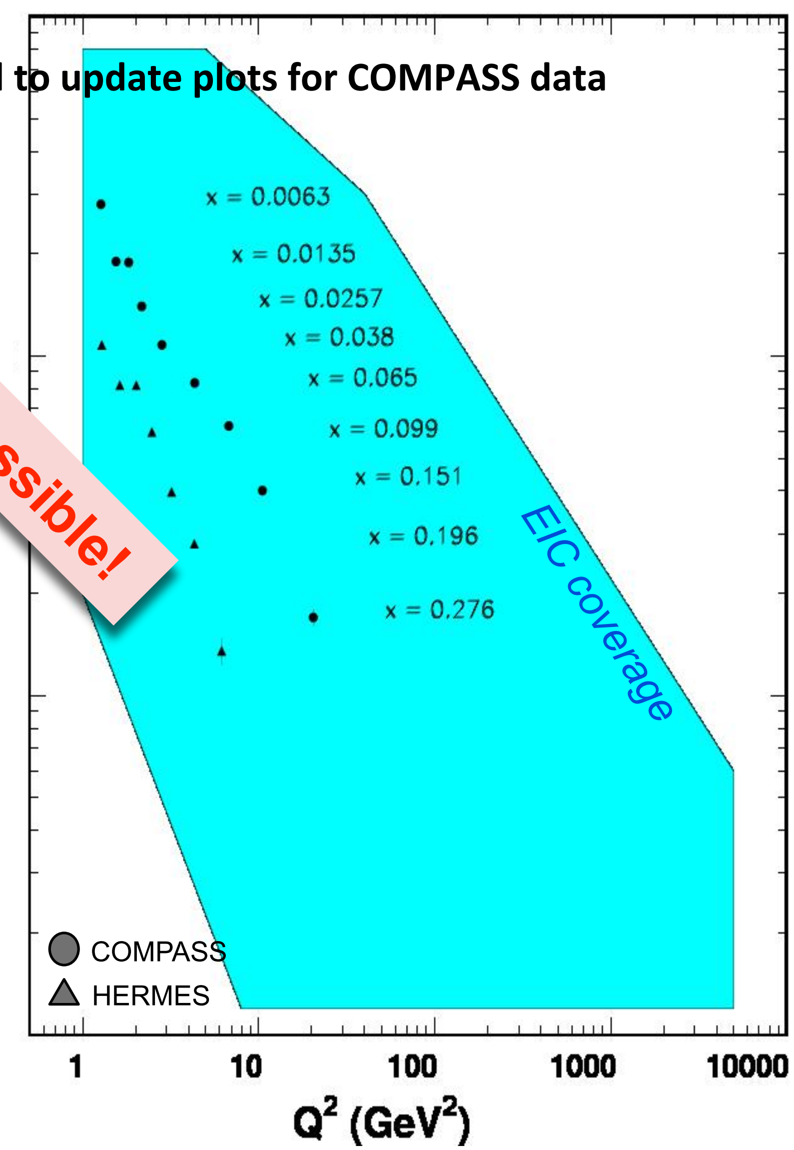
momentum



spin

An EIC makes it possible!

Note: need to update plots for COMPASS data

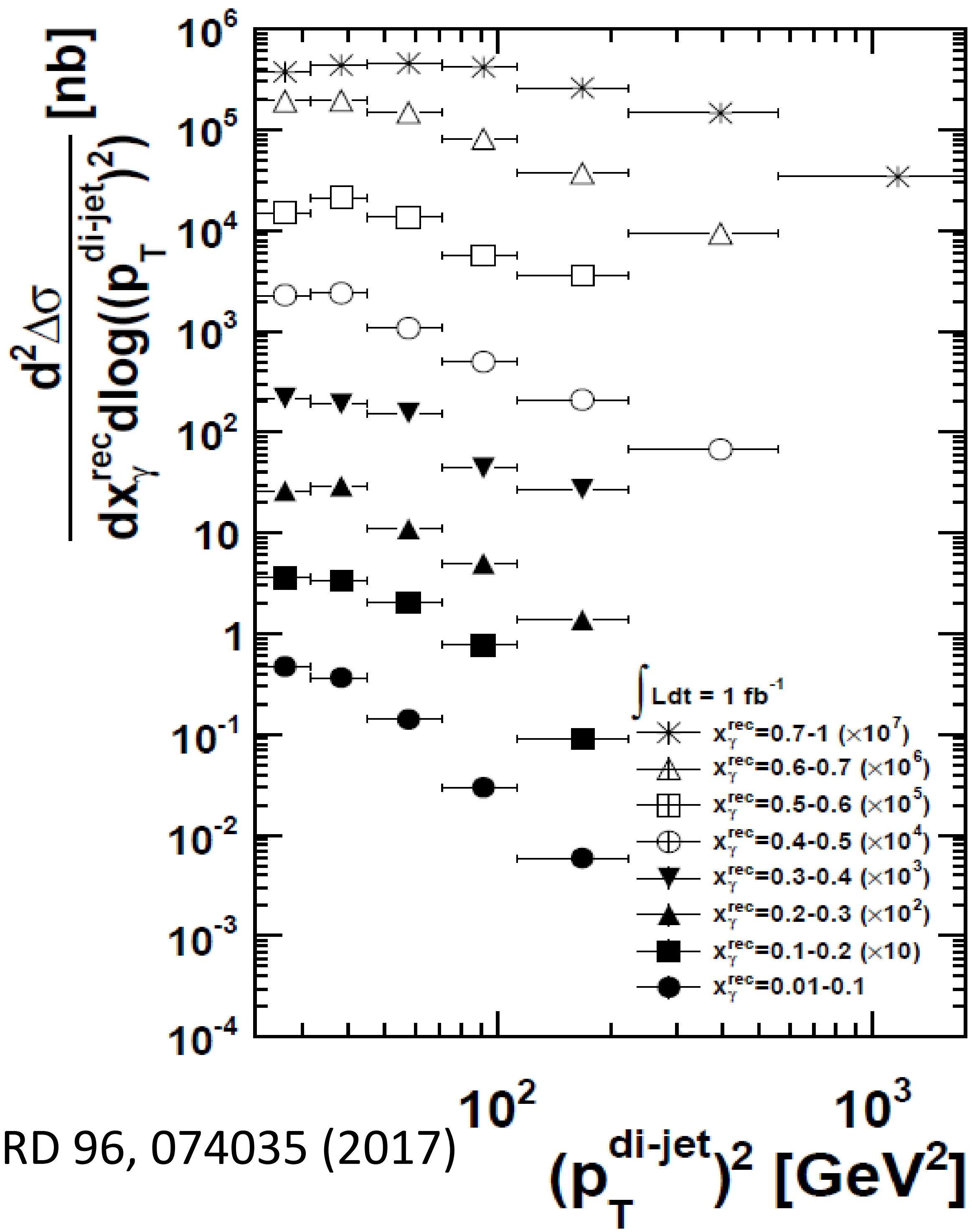


transverse spin ~ angular momentum

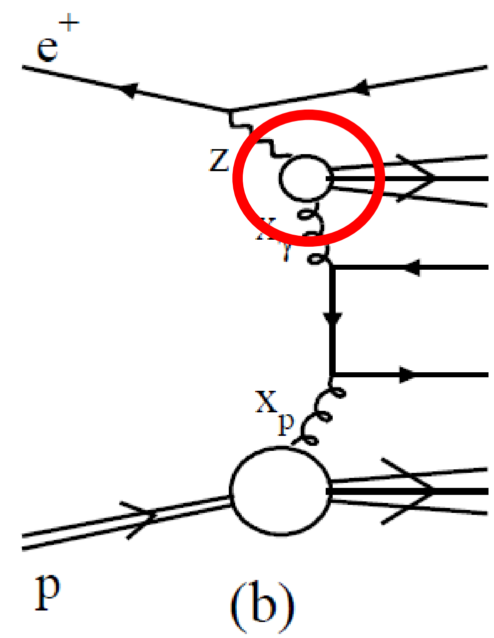
Jet Physics at an EIC

Brian Page

Example: Photon Structure



PRD 96, 074035 (2017)



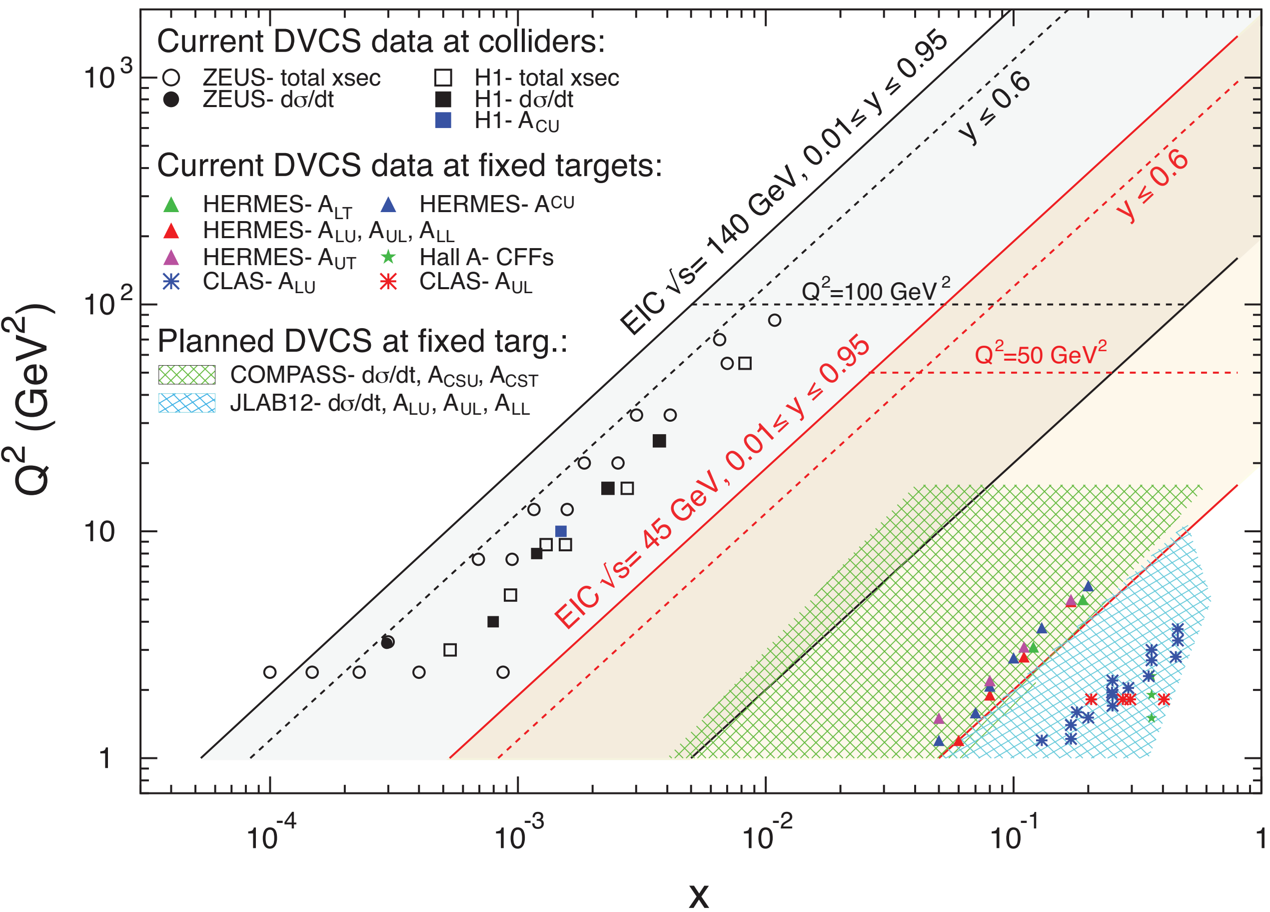
Study the polarized and unpolarized hadronic structure of the photon

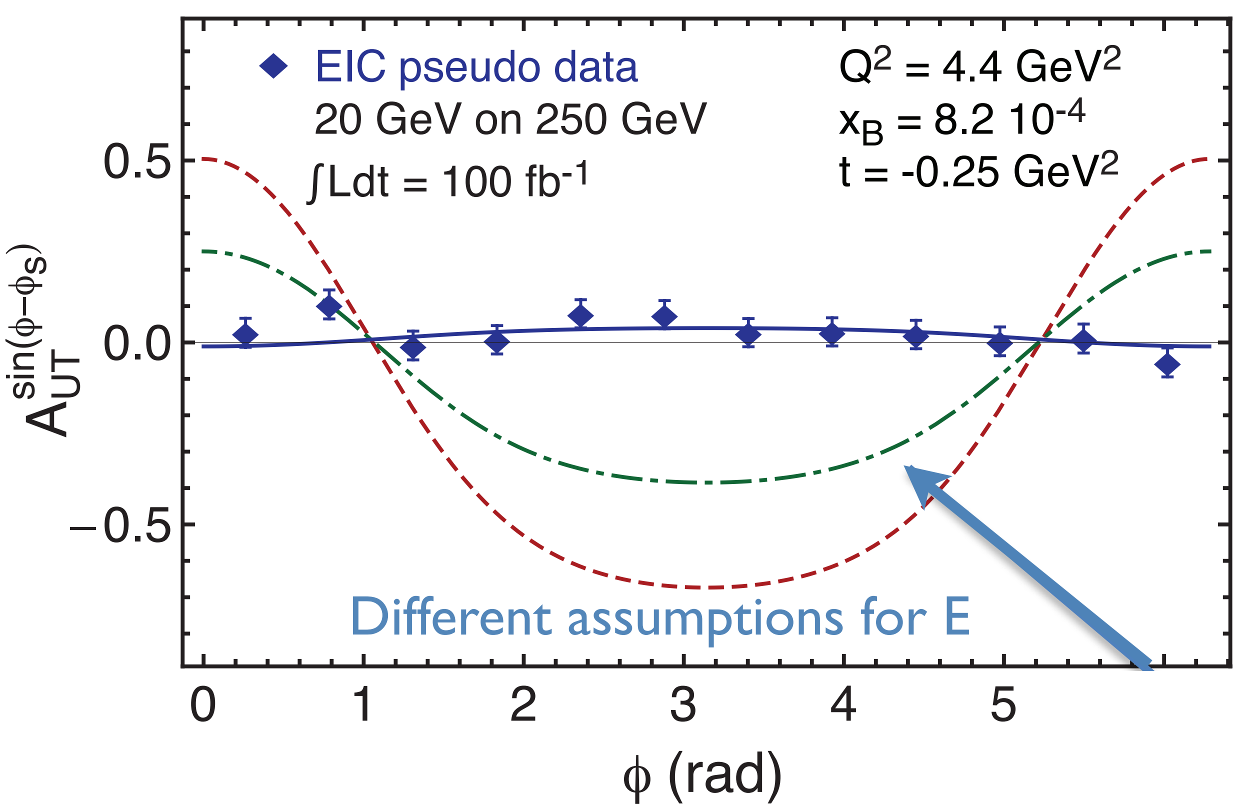
- In QCD, the photon can be considered a superposition of a bare photon state and a hadronic state
- Want to characterize the polarized and unpolarized structure of this hadronic state (photon PDFs)
- EIC cross section data will allow very precise extractions of these PDFs and give access to the polarized structure for the first time

Spin Physics at EIC

Salvatore Fazio

Studies of GPDs





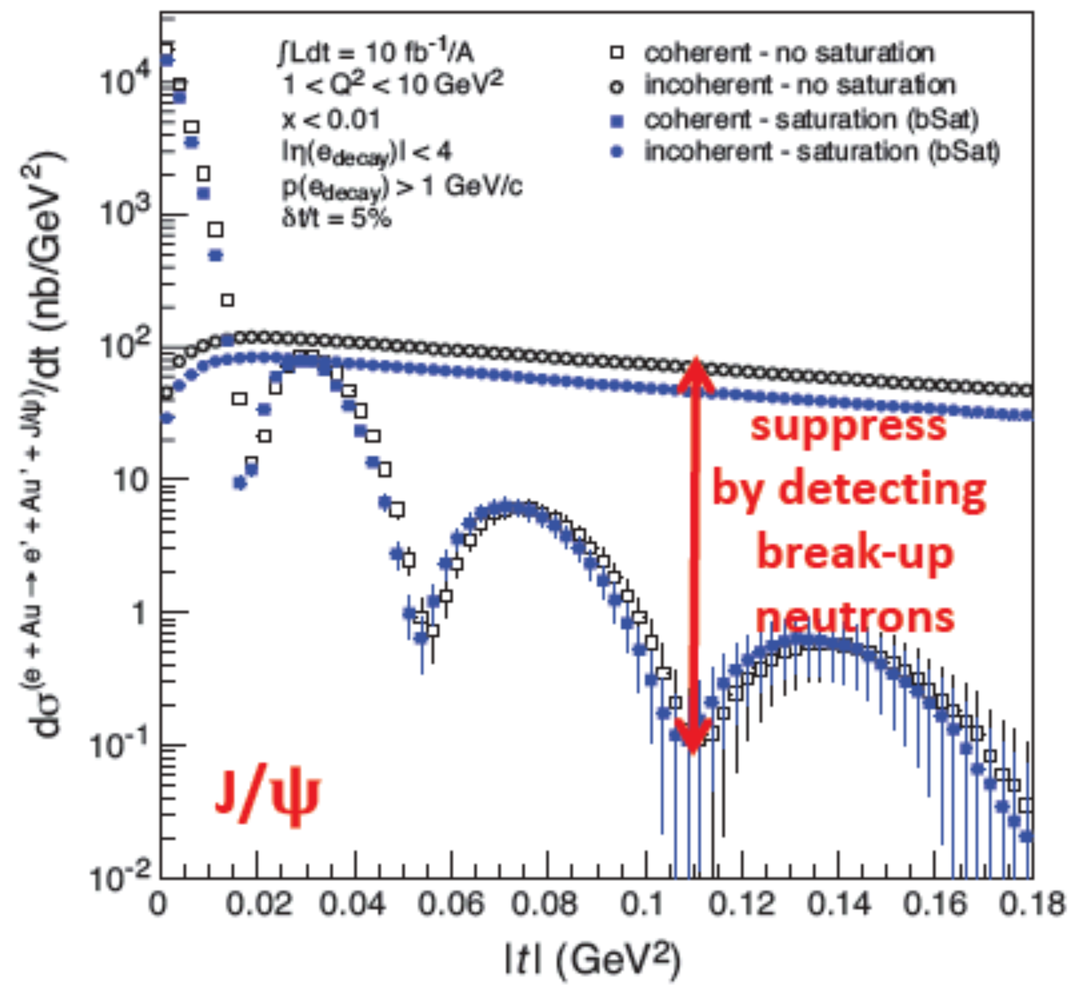
Imaging Gluons in Nuclei

Diffractive physics in eA

→ Measure spatial gluon distribution in nuclei

→ Reaction: $e + Au \rightarrow e' + Au' + J/\psi, \varphi, \rho$

→ Momentum transfer $t = |p_{Au} - p_{Au'}|^2$

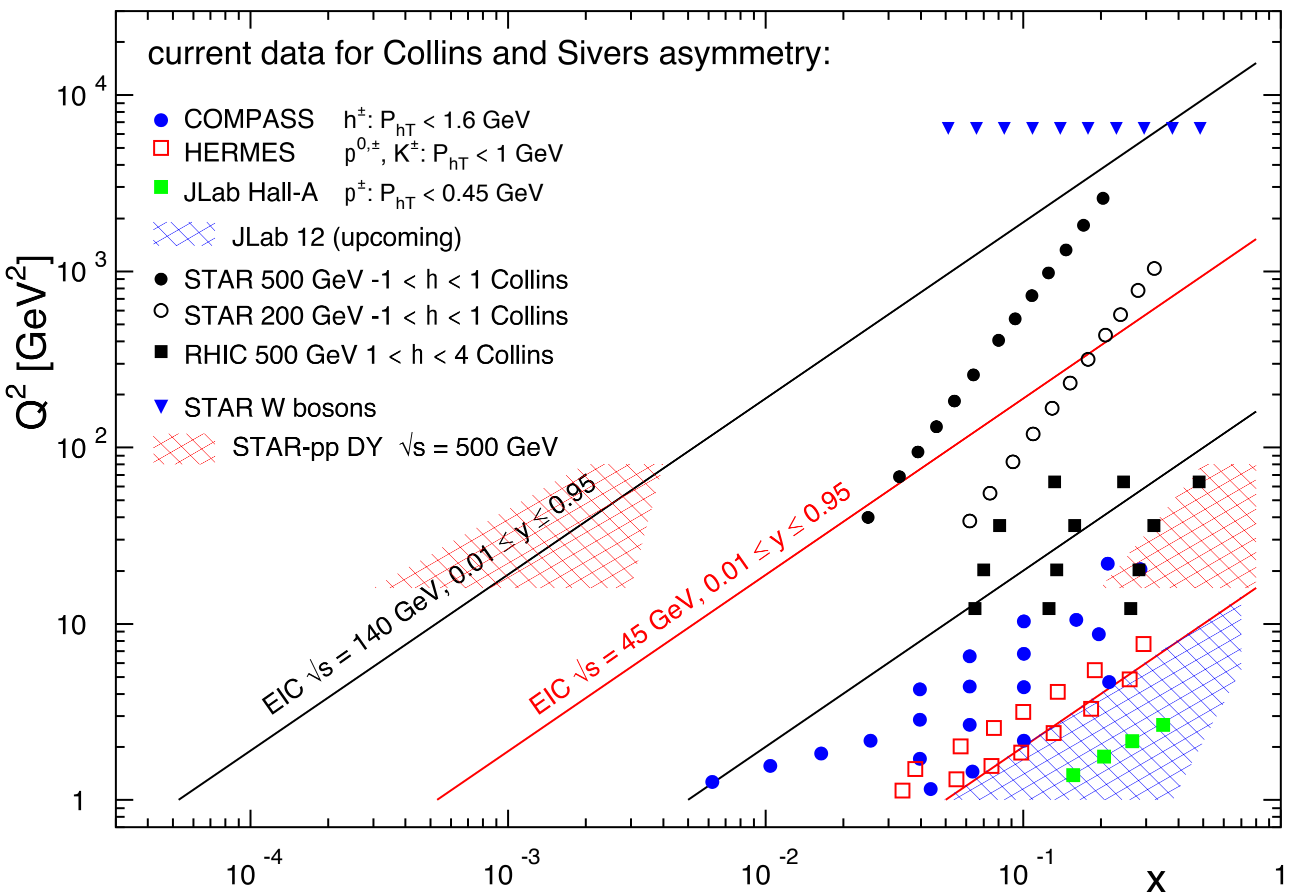


Physics requires forward scattered nucleus needs to stay intact

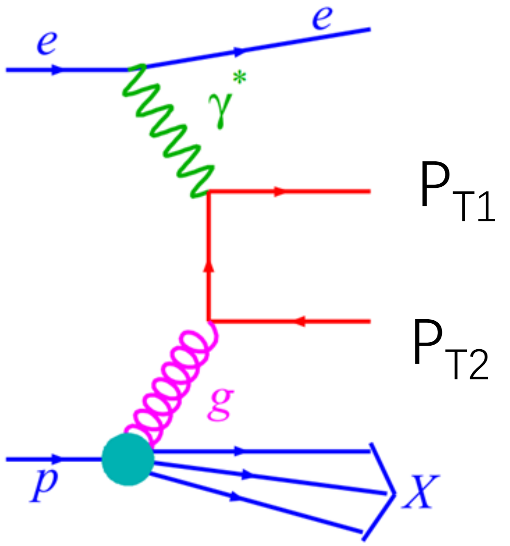
→ Veto breakup through neutron detection

Spin Physics at EIC
Accessing the Gluon Sivers Function

Liang Zhang



Photon-gluon fusion (PGF)



Single Spin Asymmetry (SSA)

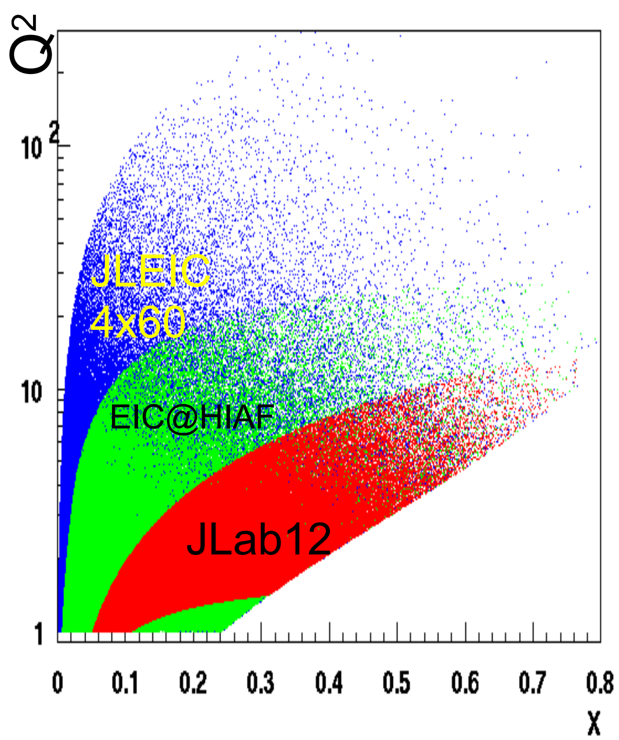
$$A_{UT} = \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}} \propto \frac{\Delta^N f_{g/p^{\uparrow}}(x, k_{\perp})}{f_1^g(x_g, k_{\perp})}$$

- The Gluon Sivers Function can be uniquely accessed at EIC.
- Dihadron and dijet methods are statistically more favored than open charm production.

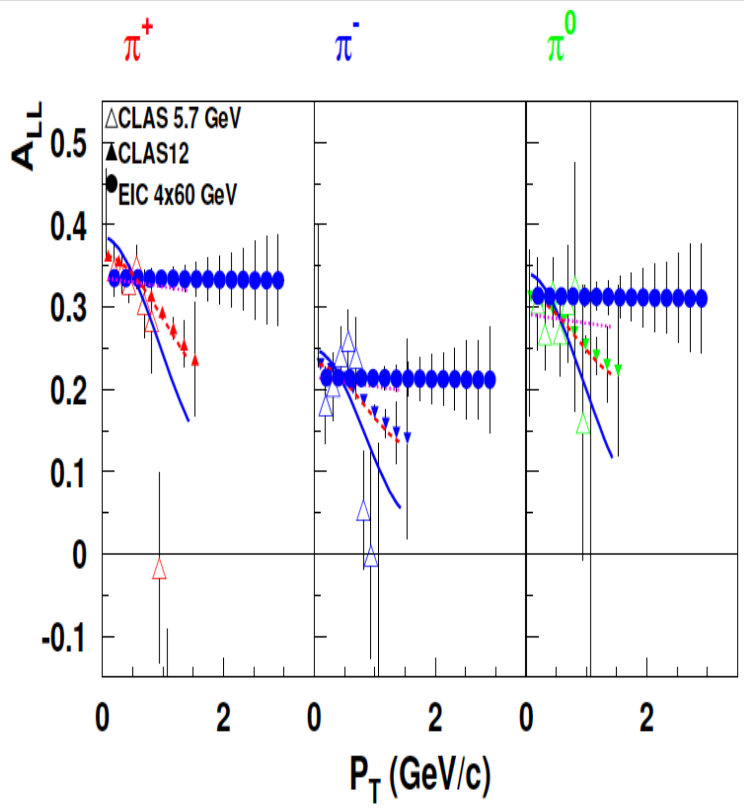
3D Nucleon Structure from JLab to EIC

Harut Avakian

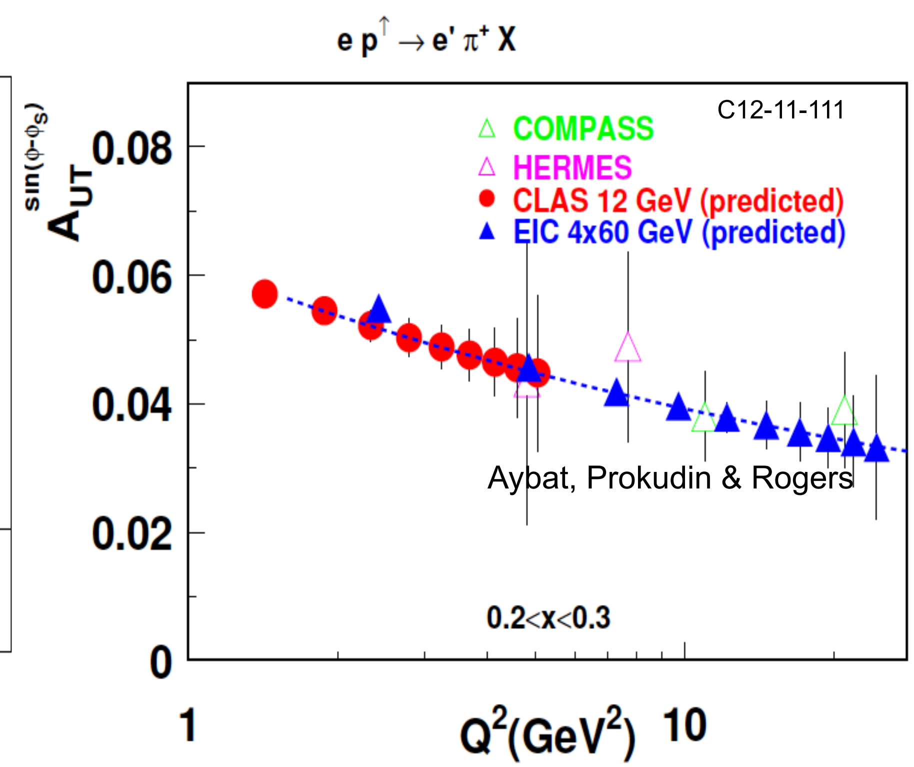
Evolution and k_T-dependence of TMDs



CLAS12/EIC kinematical coverage



k_T-dependence of $g_1(x, k_T)$



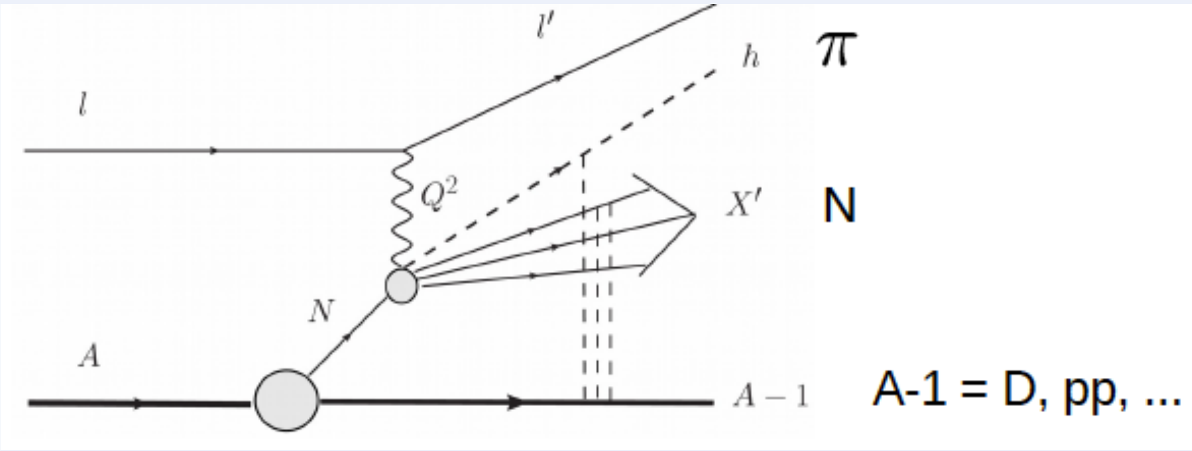
Q^2-dependence of Sivers, $f_1^{\perp}(x, k_T)$

- Large acceptance of CLAS12 allows studies of P_T and Q^2-dependence of SSAs in a wide kinematic range
- Comparison of JLab12 data with HERMES, COMPASS and EIC will pin down transverse momentum dependence and the non-trivial Q^2 evolution of TMD PDFs in general, and Sivers function in particular.

Spin Physics at JLab and EIC

Alessio DelDotto

Neutron Spin Structure from (polarized) spectator (SI)DIS on ^{3}He target



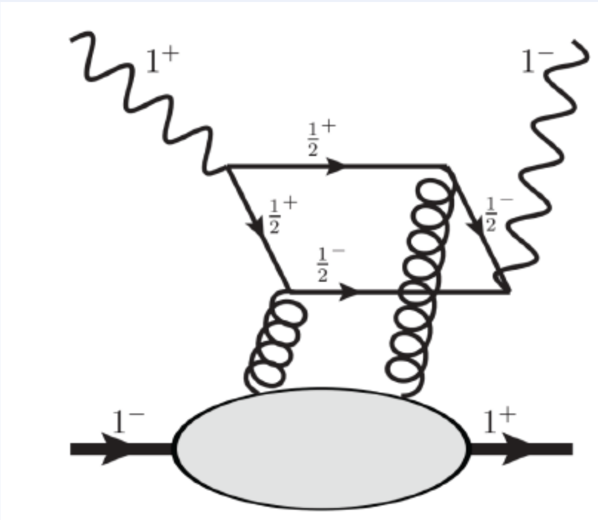
g_1: n data needed for x<0.04 and x>0.4; Q^2>1 at very small x

- A-1=D→g_1^p (test of FSI)
- A-1=pp→g_1^n

Studies of kinematic coverage, detector requirements, and projected uncertainties are ongoing.

James Maxwell

Search for Exotic Glue in Nuclei

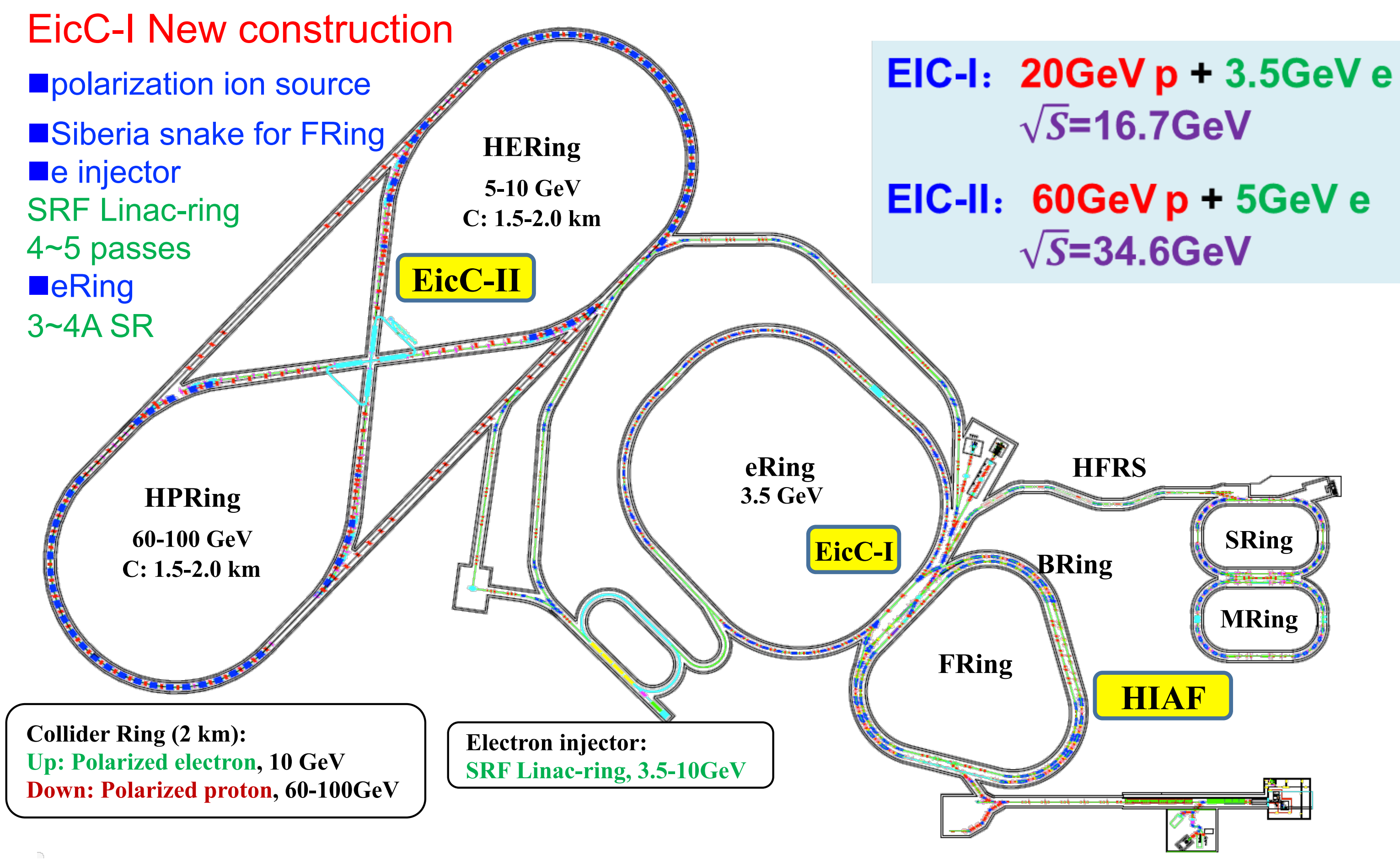


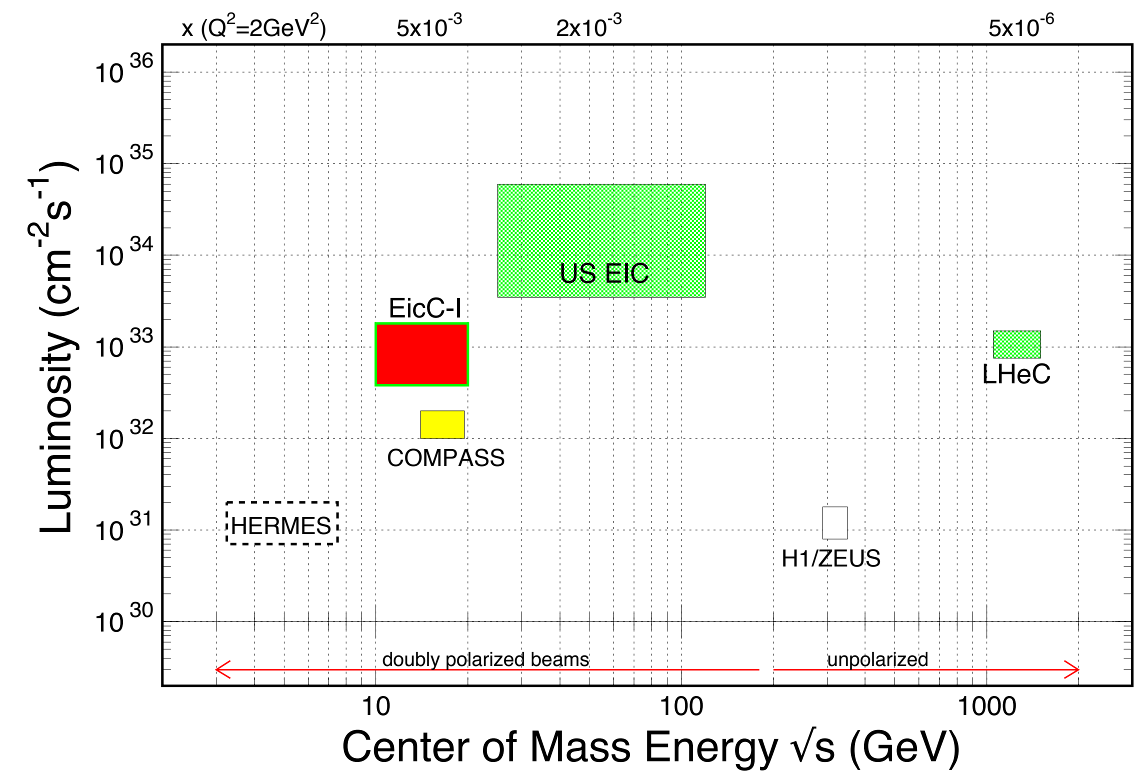
double-helicity structure function $\Delta(x,Q^2)$

- In nuclei: from gluons not associated with individual nucleon
- DIS with Unpolarized e beam on transversely polarized nuclear target with spin≥1
- Clever choice of target polarization direction to cancel out contributions from tensor structure functions b_1, b_2
- Various extraction methods (vector and tensor polarizations)
- $^{14}NH_3$ target in Hall C
- EIC: ^{6}Li (P:88%), ^{23}Na (77%)

Electron-Ion Collider in China (EICC)

Xurong Chen





C-I: will be constructed at $\sqrt{s} \sim 15 \sim 20$ GeV region

1) Focus on nuclear physics
2) B-quark hadron production

$$L \sim 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1} - 10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$$

Many thanks to all speakers and contributors!