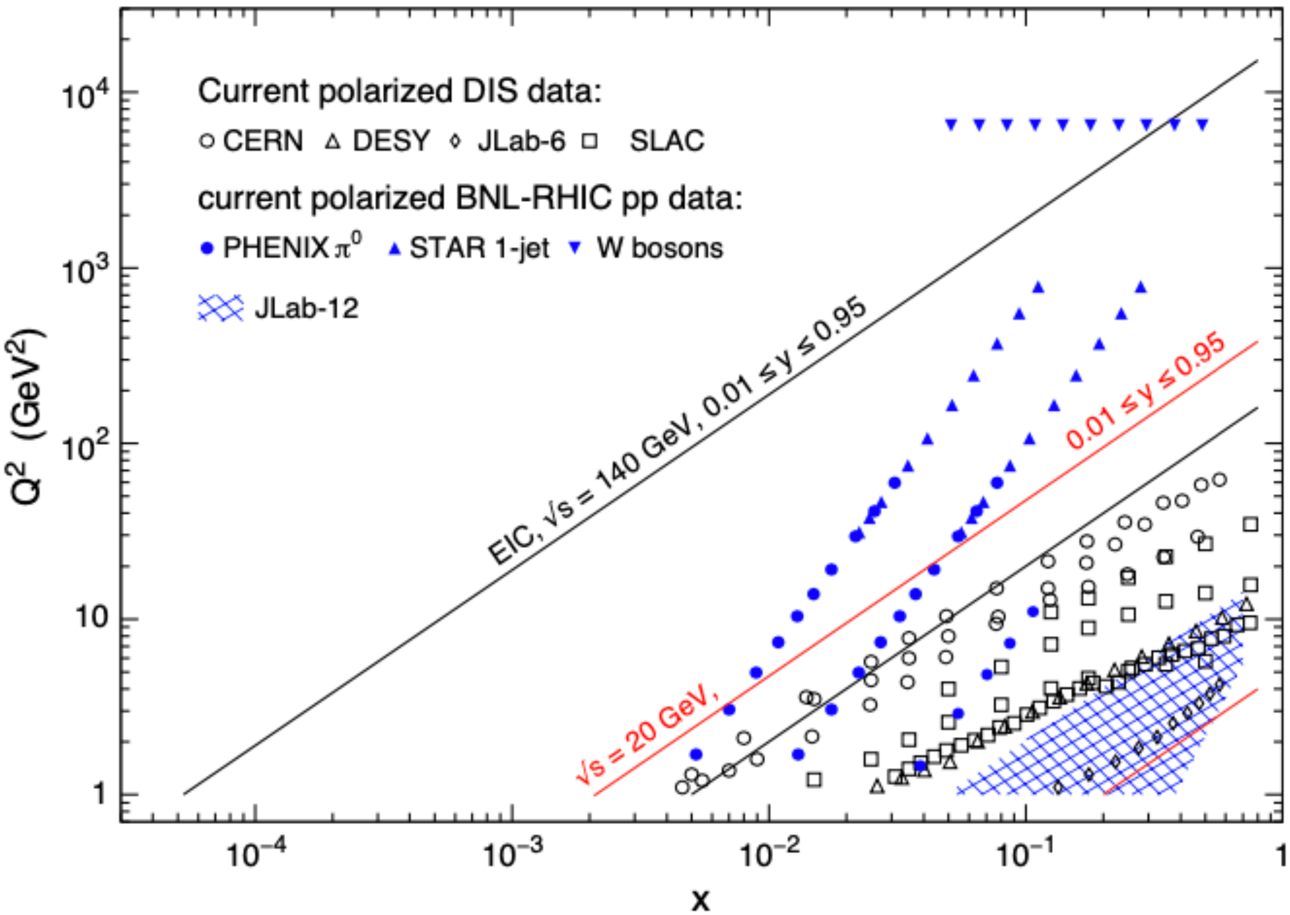
Polarized internal target experiments using the EIC beams

Bogdan Wojtsekhowski, Jefferson Lab

- Physics motivation
- Known proposals and experiments
- Parameters of the setup with EIC beams

Kinematical reach



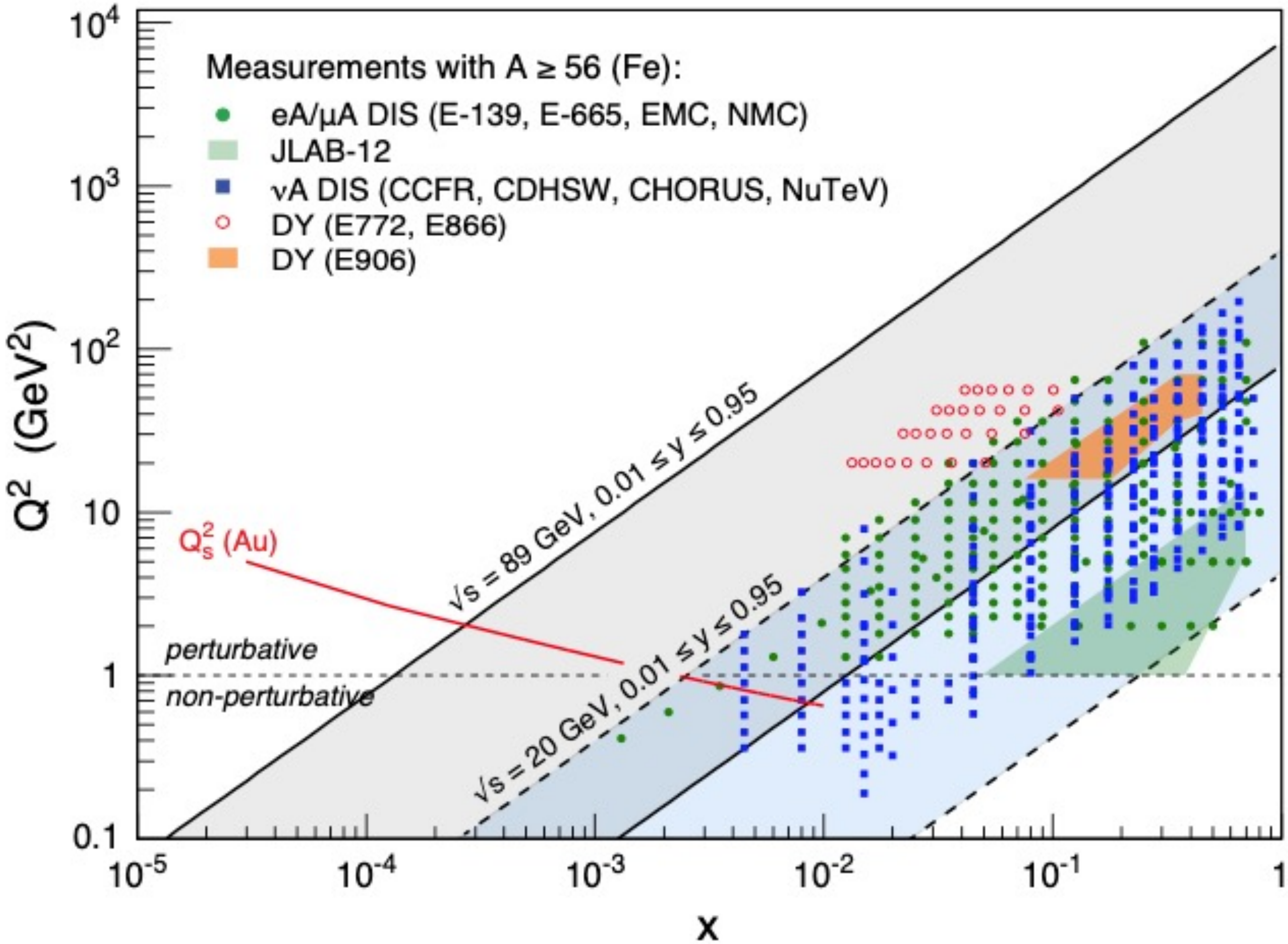


Figure 6.4: The kinematic coverage of the EIC for DIS on nuclei compared to that of previous experiments. The expected "saturation scale" $Q_s^2(x)$ for non-linear gluon dynamics in a large nucleus is indicated by a red line [40–42].

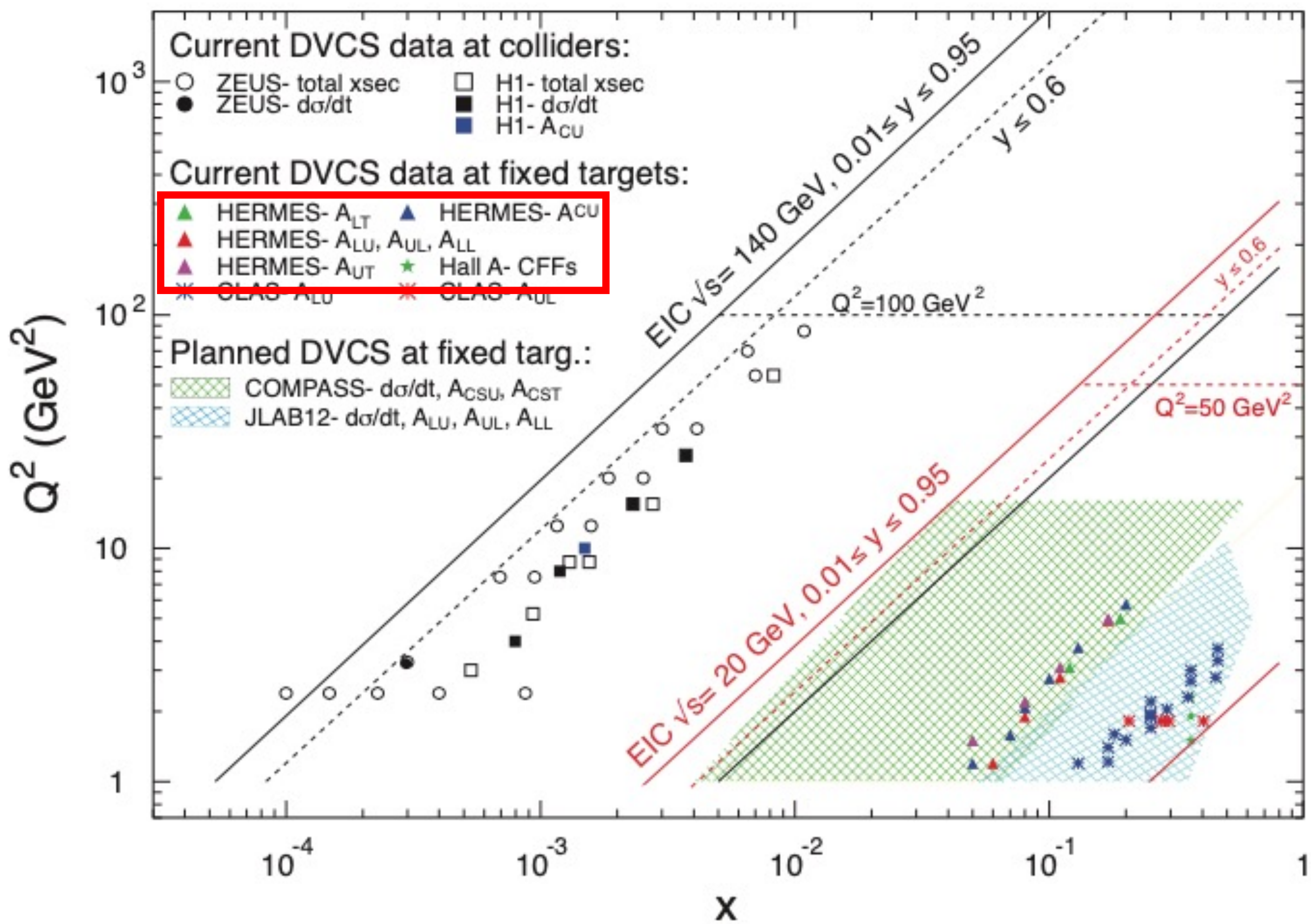
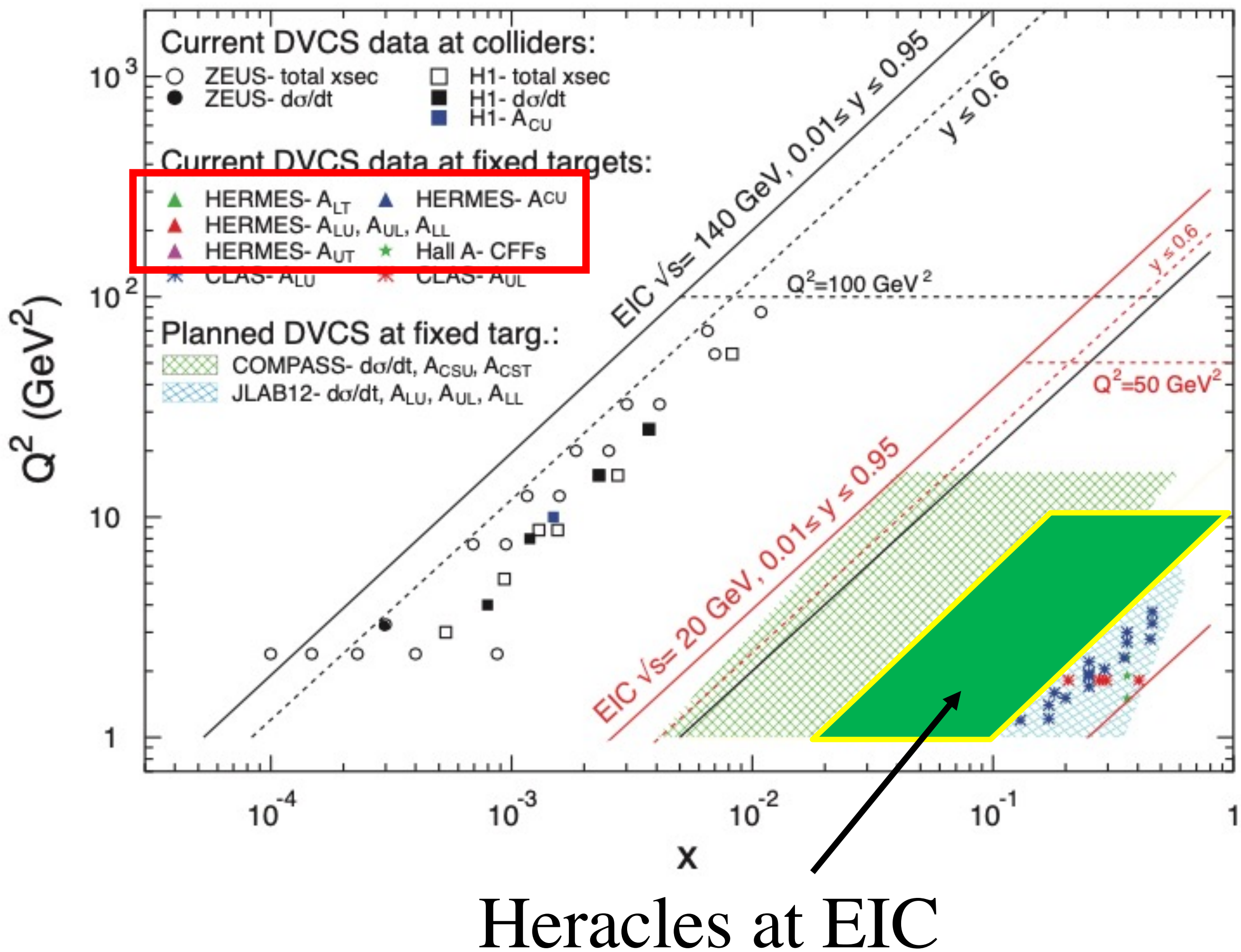
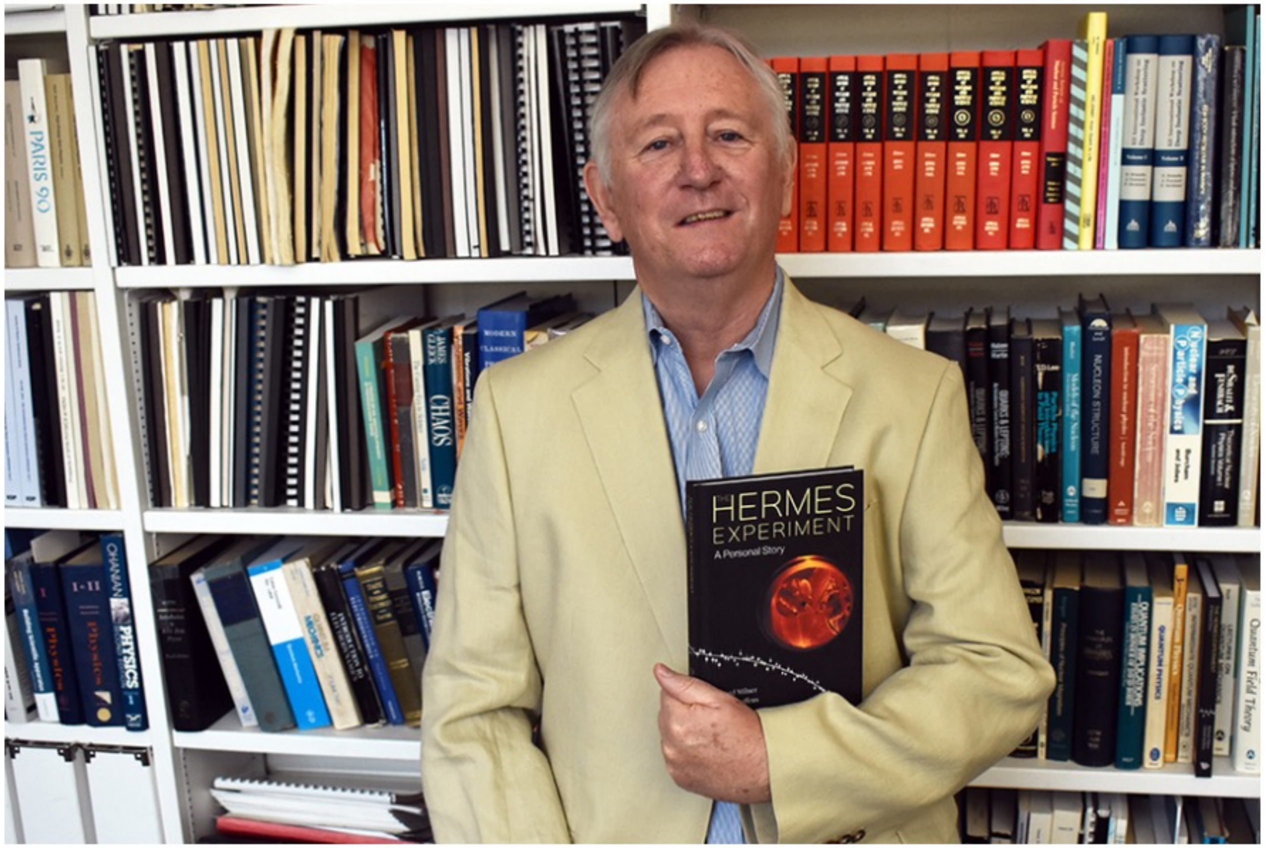


Figure 6.2: The kinematic coverage of the EIC for the DVCS process compared to other DVCS experiments.

Kinematical reach of the experiments

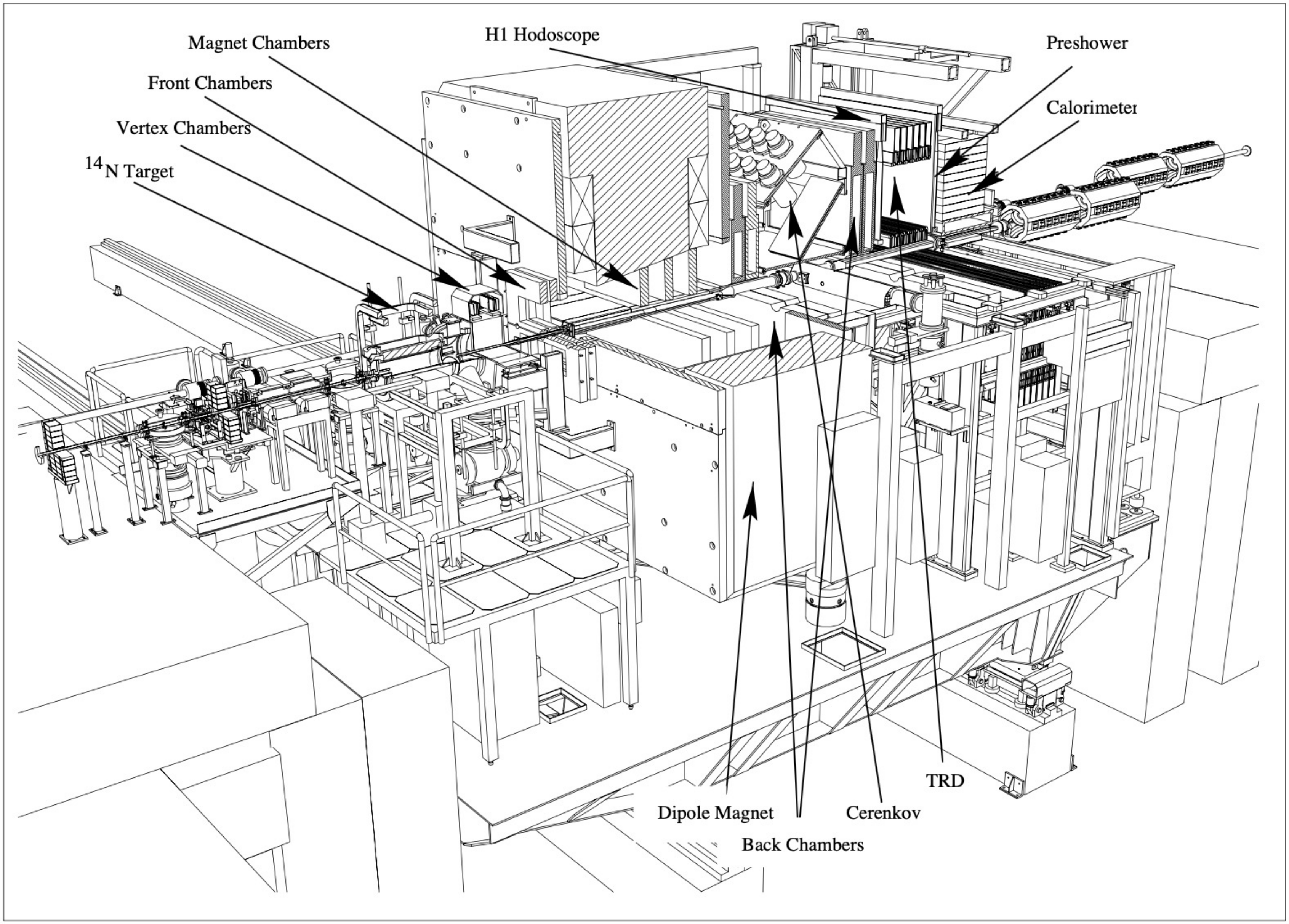


The HERMES book

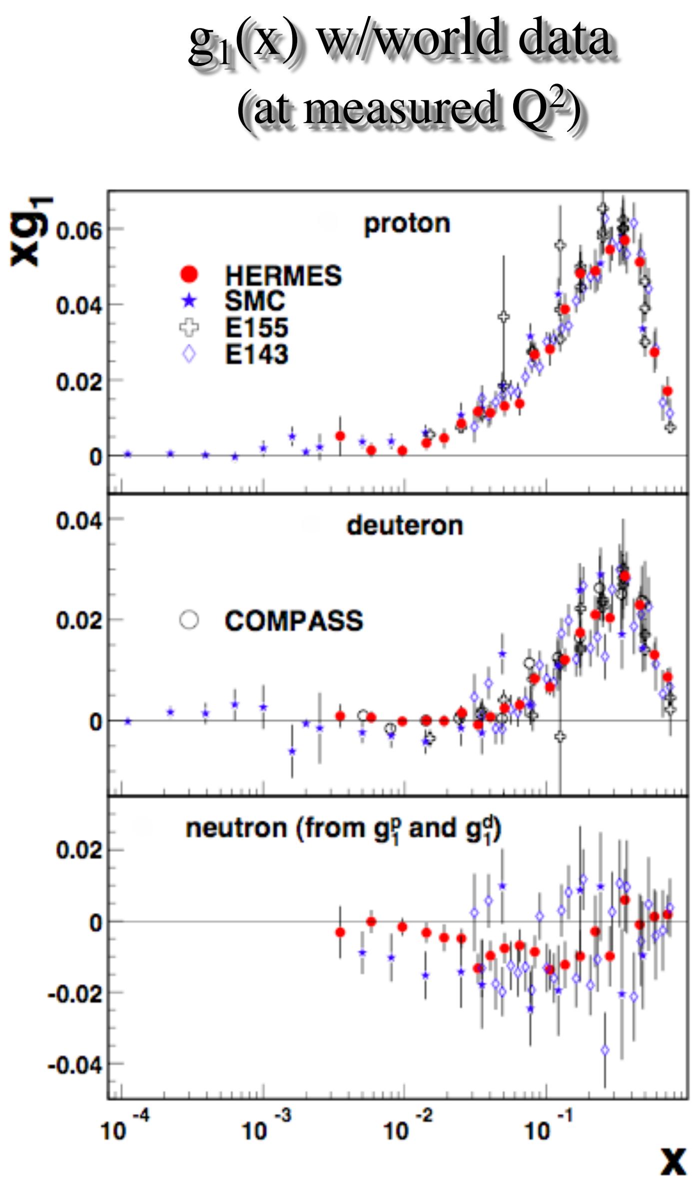


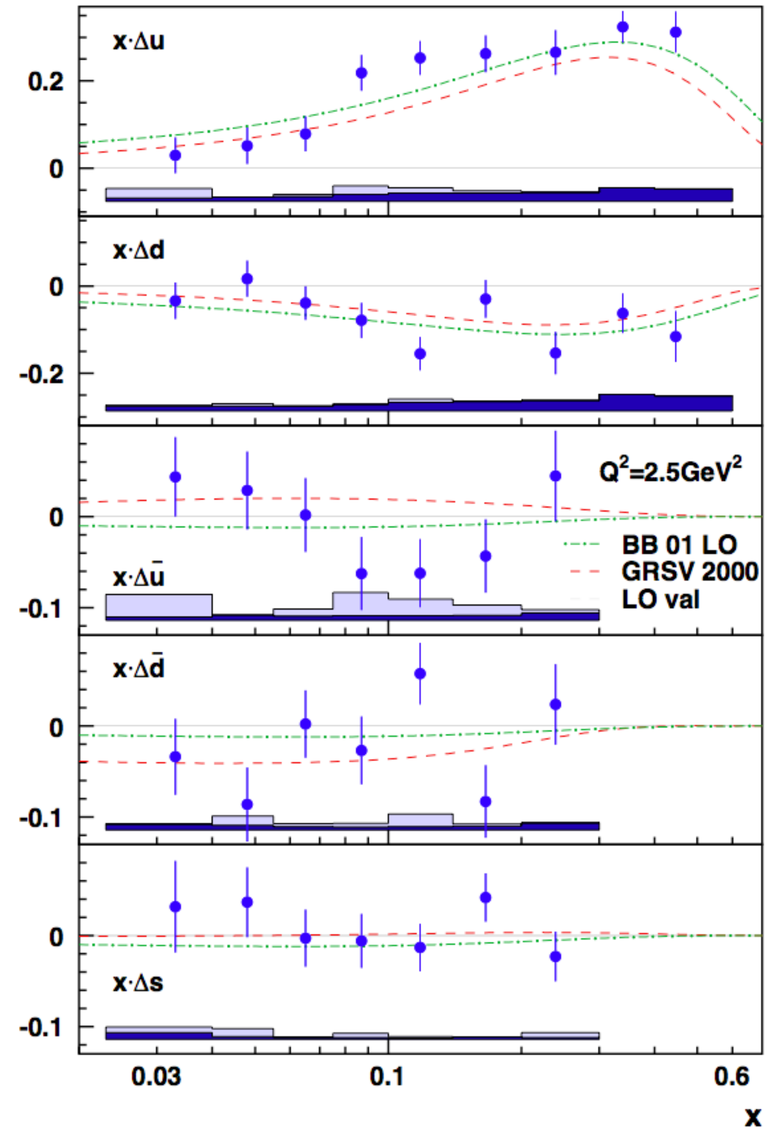
"The Hermes Experiment," a new book by MIT physics Professor Richard Milner and FAU Erlangen-Nurnberg Professor Erhard Steffens, tells the story of how several hundred physicists

The HERMES spectrometer

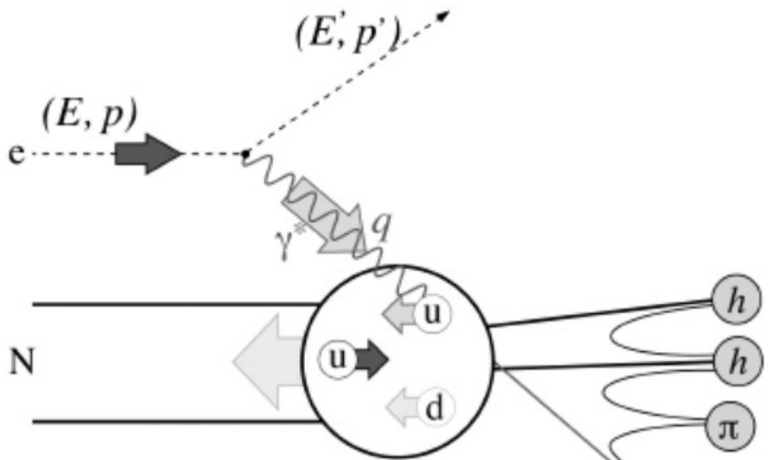


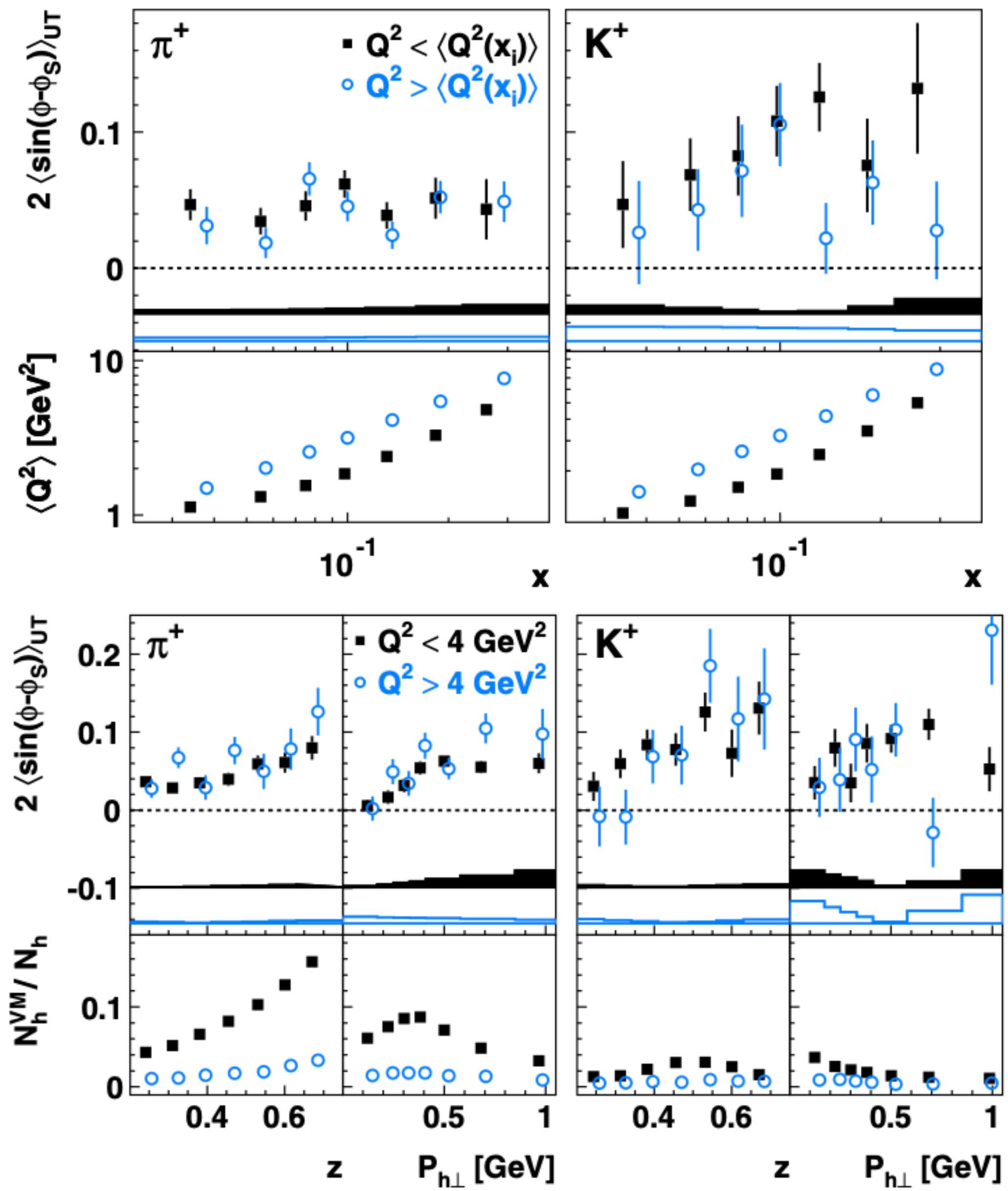
The HERMES physics results





The HERMES physics results





PEGASYS/Mark II:
A Program of Internal Target Physics Using the Mark II Detector at the PEP Storage Ring

III. PHYSICS EXPERIMENTS

- III.A Quark Hadronization in Deep Inelastic Scattering
- III.B Nuclear Transparency in Exclusive Electroproduction Reactions
- III.C Azimuthal Distributions of Leading Hadrons from the Nucleon
- III.D Cumulative Production; Tagged Structure Functions
- III.E Study of Inelastic and Quasi-elastic Scattering at Large x_{Bj}
- III.F Nuclear Response to Deep Inelastic Scattering
- III.G Inclusive Virtual Compton Scattering
- III.H Exclusive Virtual Compton Scattering
- III.J Precision Measurement of Internal Bremsstrahlung
- III.K J/ψ Production
- III.L Open Charm Production
- III.M Exclusive Kaon Production from the Proton and Deuteron
- III.N Search for New Particles Coupling only to Leptons
- III.O Bose-Einstein Correlations in $eA \to e'\pi^{\pm}\pi^{\pm}X$

PEGASYS – A PROPOSED INTERNAL TARGET SPECTROMETER FACILITY FOR THE PEP STORAGE RING

Karl VAN BIBBER

Department of Physics, Lawrence Livermore National Laboratory, PO Box 808, L-405, Livermore, CA 94550, USA

A proposal for an internal gas-jet target and forward spectrometer for the PEP storage ring is described. The beam structure, allowable luminosity ($\mathscr{L} = 10^{33}$ cm^{-2} s^{-1} for H_2, D_2 decreasing as $Z^{-1.75}$ for nuclear targets) and energy ($E_e \leq 15$ GeV) make the ring ideal for multiparticle coincidence studies in the scaling regime, where perturbative QCD may be an apt description of some exclusive and semi-inclusive reactions.

1. Introduction

The utility of storage rings for coincidence measurements, and for applications where ultrathin targets are required or are the only targets available, is well known and will not be elaborated on further [1]. An internal target facility at the PEP storage ring, PEGASYS (*PE*P *ga*s jet *s*pectrometer *sys*tem), would provide unique opportunities in the Bjorken scaling regime, and complement the programs at SLAC End Station A, the Tevatron muon facility and CEBAF in the future.

the desired storage lifetime. Fig. 1 shows that the luminosity of H_2 and D_2 may be 10^{33} cm^{-2} s^{-1} for target thicknesses of 10–20 ng/cm^2; the luminosity (in terms of *nuclear* scattering centers) decreases roughly as $Z^{-1.75}$. This luminosity results from, e.g., a 20 mA current and a 2 h beam lifetime. In practice, the time in between fills with probably be 4–12 h, but the current can be higher if running at less than full energy.

The PEP ring will continue to operate for high-energy physics (the TPC collaboration) in the intermediate term. A synchrotron radiation physics program has begun at PEP and promises long term stability for the machine.

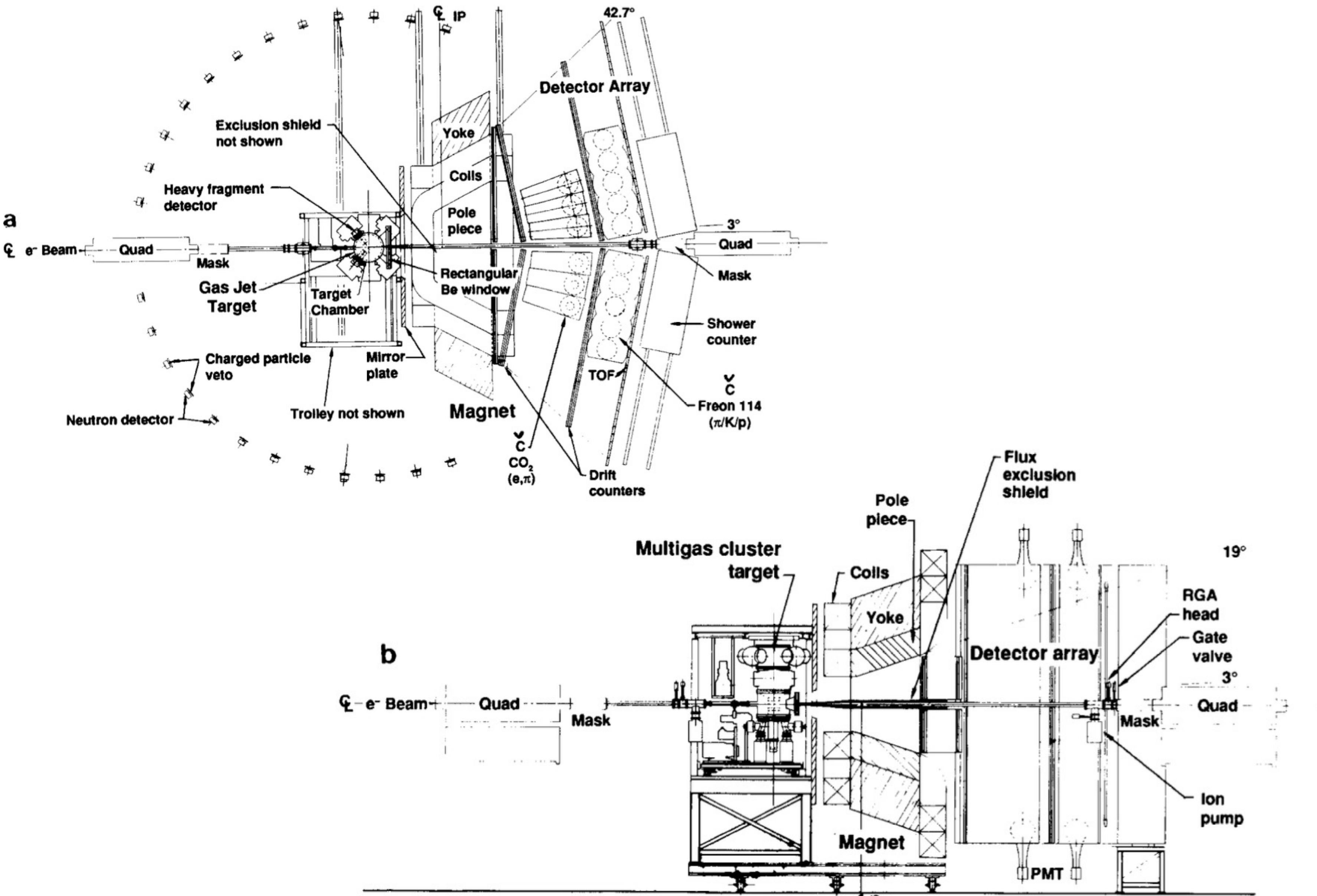


Fig. 2. Schematic top (a) and side (b) views of the proposed spectrometer and gas jet target. A shaped iron plate with a concentric soft iron pipe in its bore will occupy the spectrometer mid-plane to exclude flux from the beam path.

Project Overview

Original Proposal

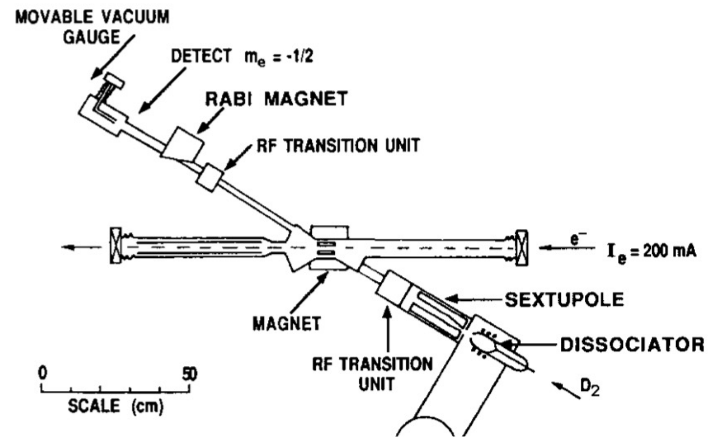
The PEGASYS Collaboration, which formed in November, 1986, proposed an experimental program to study multiparticle final states in electron deep inelastic scattering from nucleon and nuclear targets, using electrons of up to 15 GeV in the PEP storage ring. The Collaboration developed a detailed design for a facility consisting of a large-aperture forward spectrometer, a cryogenic gas jet target, and some particle detection capability at backward angles.

The capital construction costs of this facility were estimated to be approximately $15M, and would have been borne by the DOE Office of Nuclear Physics, SLAC, and the Institute for Theoretical and Experimental Physics in Moscow who would have provided the 600-ton magnet. Construction was estimated to take approximately 3 years after funding.

35 years later the cost could be of $60M

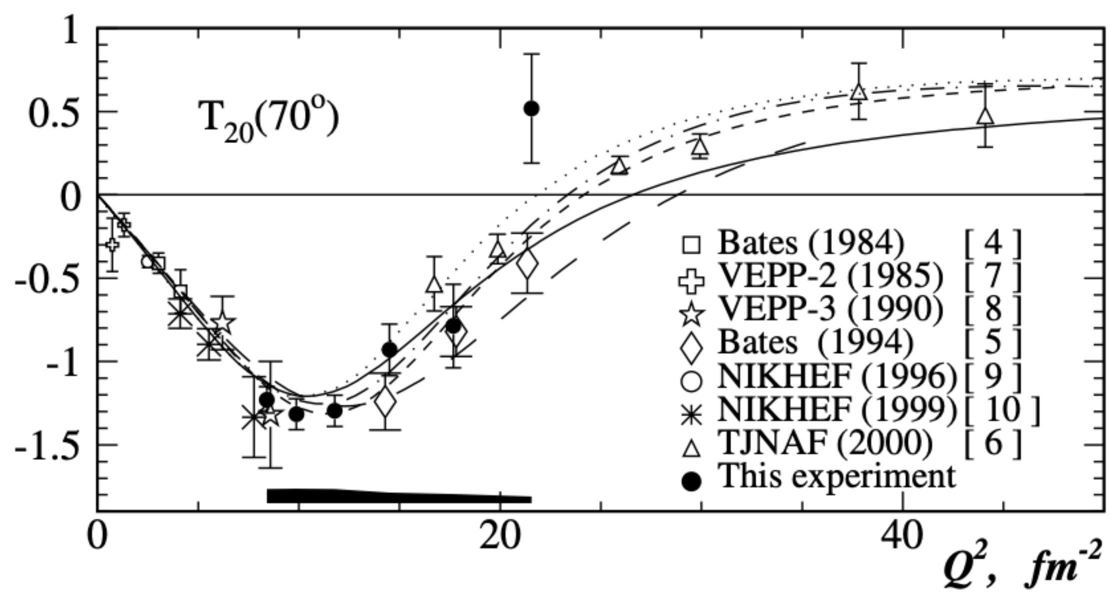
Polarized internal target experiments at BINP

T20 team in 1986



Modern developments in nuclear physics

at Novosibirsk, 1987



T20 results in 2003

Beam induced target depolarization

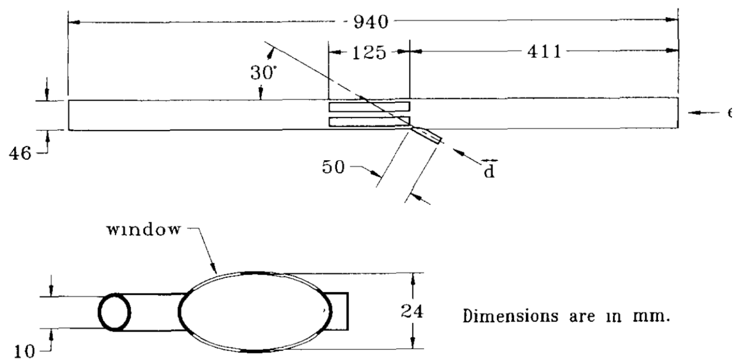


Fig. 2. Detailed drawing of Stage I cell used in VEPP-3.

Discovered on 1/15/1988

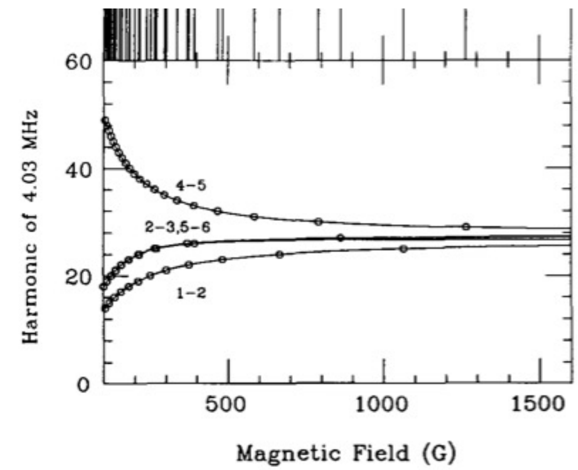
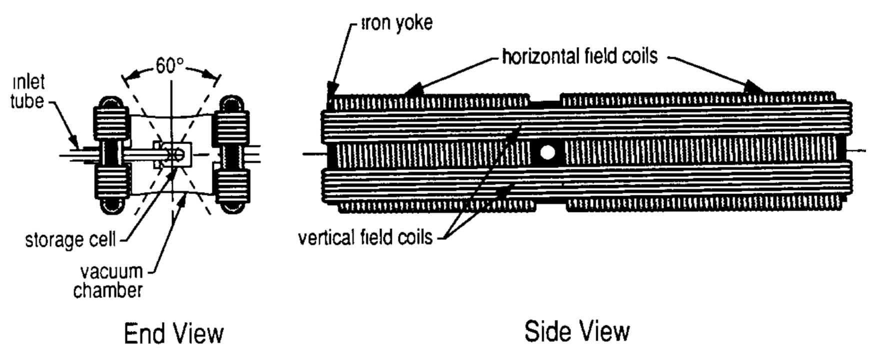


Fig. 3. Magnetic fields strengths at which resonant depolarization occurs in VEPP-3. The upper half represents the magnetic field of each resonance as a vertical line.

NIM A327 (1993) 277-286

NIM A350 (1994) 423-429



Open magnet for a long cell target

The Electron-Ion Collider – Accelerator Design Overview

Andrei Seryi
Associate Director for Accelerator Systems and International Partnership

2021 EIC UG Meeting Early Career Workshop

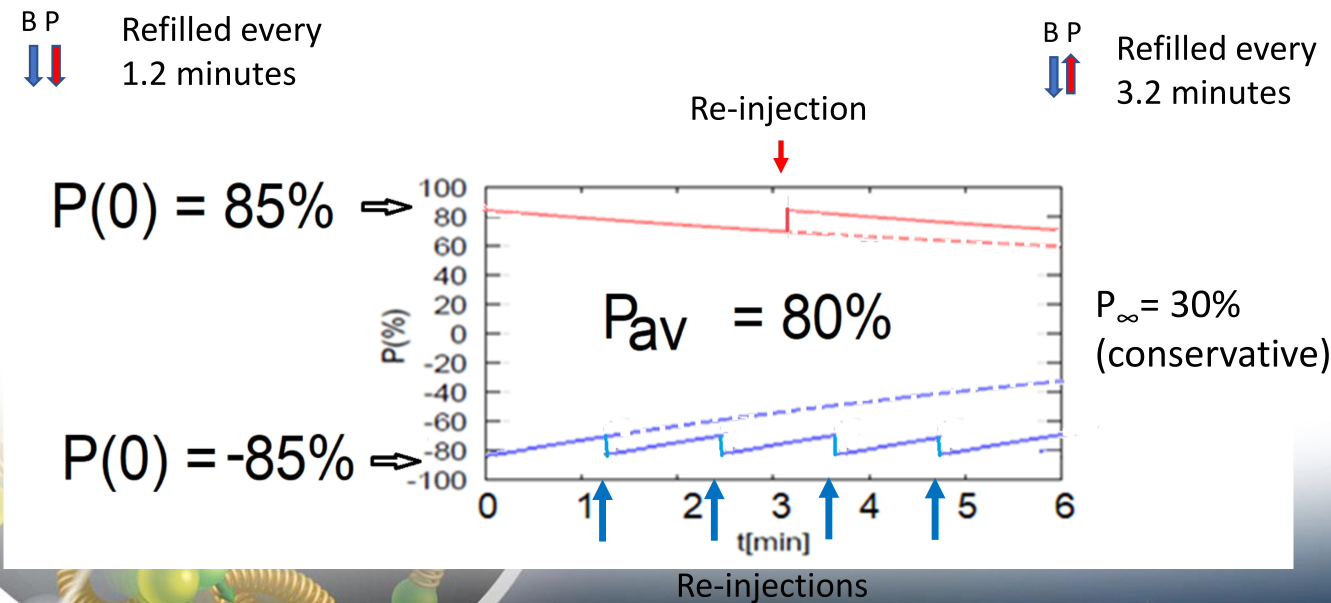
29 July 2021

Electron-Ion Collider

BROOKHAVEN NATIONAL LABORATORY · Jefferson Lab · U.S. DEPARTMENT OF ENERGY | Office of Science

High average polarization at electron storage ring of 80% by

- Frequent injection of bunches on energy with high initial polarization of 85%
- Initial polarization decays towards P_∞ < ~50%
  (equilibrium of self-polarization and stochastic excitation)
- At 18 GeV, every bunch is refreshed within minutes with RCS cycling rate of 2Hz
- Need both polarization directions present at the same time



Electron-Ion Collider

The HERMES at EIC (Heracules)

Physics: polarized TDIS, SIDIS, and DVCS

Detector like HERMES with GEM-based trackers +

Luminosity up to a few 10^{35} /cm^2/s

Highly polarized proton and deuteron/He-3
atoms, including transverse pol.
unique case for d (tensor polarization)

Heracles parameters vs. HERMES

EIC beam energy: E:	18 GeV vs. 27.5 GeV
EIC beam intensity, I_b:	2500 mA (at 10 GeV) vs. 50 mA
	227 mA (at 18 GeV)
EIC beam polarization, P_b:	80% vs. 40%
Target thickness, t_t :	25 larger than at HERA (thanks to pol. e- injection)
Target polarization, P_t:	the same high as at HERMES

Internal target will have luminosity $L_{\text{at EIC}} \sim 10^{35}$ /cm^2/s

The experiment FOM gain: ($I_b \times t_t \times P_b{}^2 \times P_t{}^2$): ~ (5-50) x 25 x 4 x 1

A factor of 500+ larger FOM opens a field for many advances in hadron physics

Heracles parameters vs. HERMES

Internal target will have luminosity $L_{at\ EIC} \sim 10^{35}$ e-n/cm^2/s

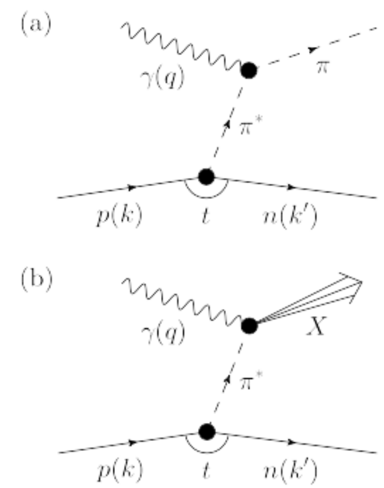
The experiment FOM gain: (I_b x t_t x $P_b{}^2$ x $P_t{}^2$): ~ (5-50) x 25 x 4 x 1

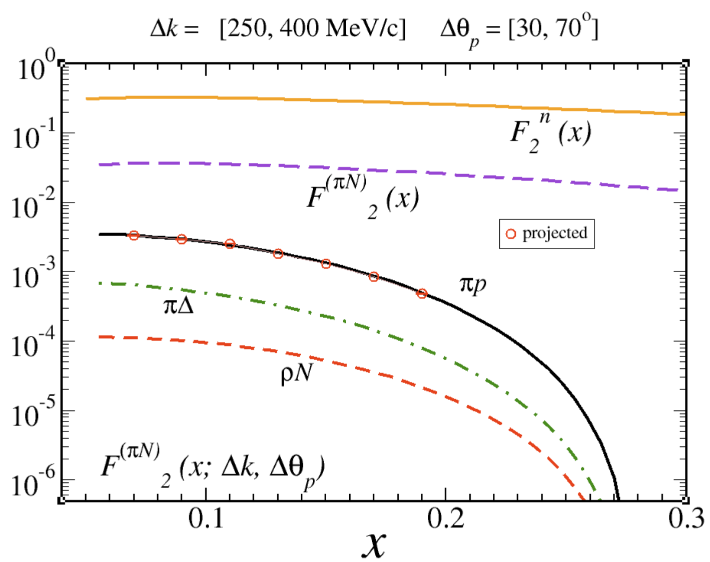
A factor of 500+ larger FOM opens a field for many advances in hadron physics

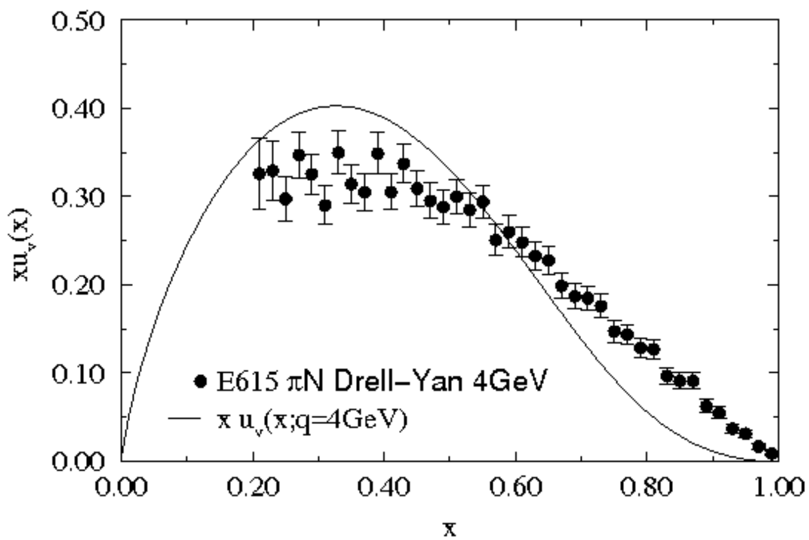
Compare, the polarized NH3 target capable to operate at $L \sim 10^{36}$ e-n/cm^2/s
However, the dilution factor is of 6, so the FOM is lower than for Heracles by a factor of 3.

The HERMES at EIC (Heracules)

Physics: polarized T(aged)DIS,
Plots: JLab experiment C12-15-006
and C. Roberts' papers







The high energy photon beam for the external polarized target

- Laser back-scattering (like LEGS, GRALL, LEPS)
  tagged, polarized photons up to ~ 8 GeV

- Radiation from a thin internal target
  tagged, circular polarized photons, up to 18 GeV

- Apollon proposal at DESY

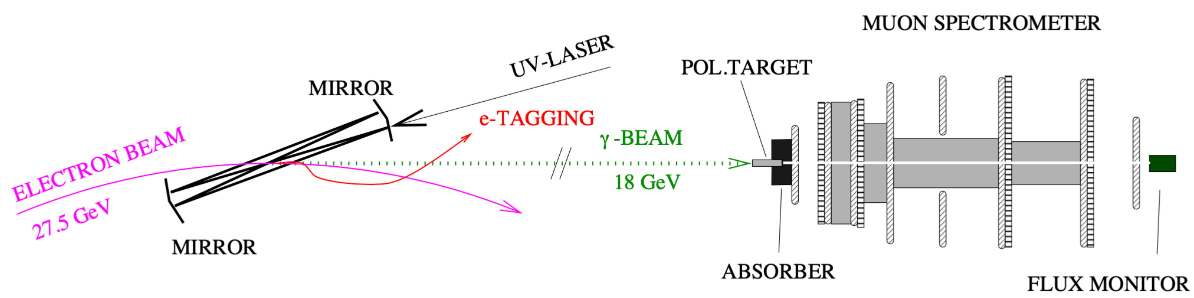


Figure 4: The basic layout of the APOLLON experiment. A laser beam is brought into collision with the HERA electron beam. The Compton backscattered high energy photons produce J/ψ mesons in a polarized target. The energy of the photons is selected by tagging the recoil electrons.

Compass/AMBER

10^7 muons on 100 cm long target ~ L ~ 10^{33}

AMBER physics program

AMBER

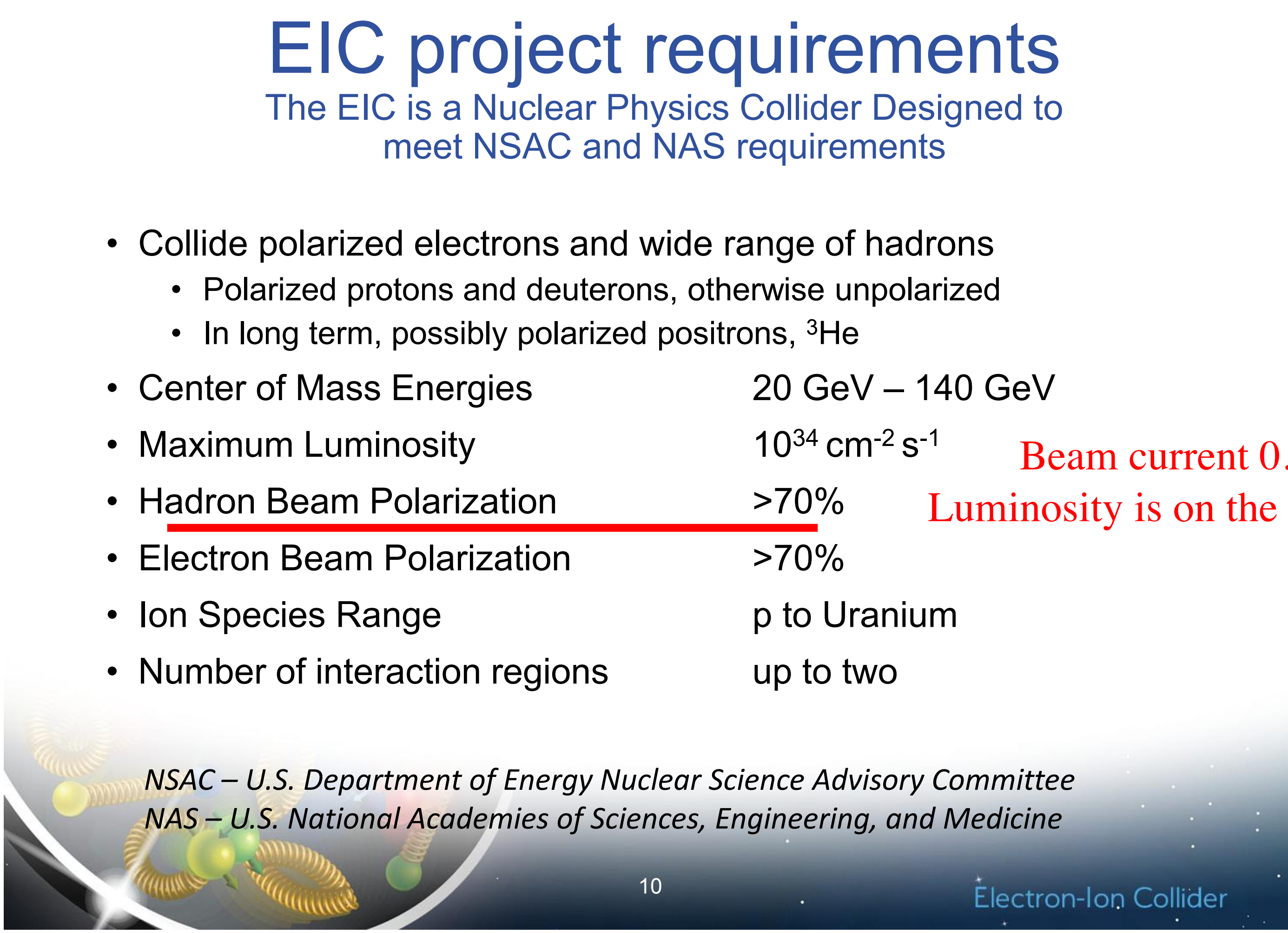
Program	Physics Goals	Beam Energy [GeV]	Beam Intensity [s^{-1}]	Trigger Rate [kHz]	Beam Type	Target	Earliest start time, duration	Hardware additions
muon-proton elastic scattering	Precision proton-radius measurement	100	$4 \cdot 10^6$	100	$\mu^\pm$	high-pressure H2	2022 1 year	active TPC, SciFi trigger, silicon veto,
Hard exclusive reactions	GPD E	160	$2 \cdot 10^7$	10	$\mu^\pm$	$NH_3^\uparrow$	2022 2 years	recoil silicon, modified polarised target magnet
Input for Dark Matter Search	$\overline{p}$ production cross section	20-280	$5 \cdot 10^5$	25	p	LH2, LHe	2022 1 month	liquid helium target
$\overline{p}$-induced spectroscopy	Heavy quark exotics	12, 20	$5 \cdot 10^7$	25	$\overline{p}$	LH2	2022 2 years	target spectrometer: tracking, calorimetry
Drell-Yan	Pion PDFs	190	$7 \cdot 10^7$	25	$\pi^\pm$	C/W	2022 1-2 years	
Drell-Yan (RF)	Kaon PDFs & Nucleon TMDs	~100	10^8	25-50	$K^\pm, \overline{p}$	$NH_3^\uparrow$, C/W	2026 2-3 years	"active absorber", vertex detector
Primakoff (RF)	Kaon polarisa-bility & pion life time	~100	$5 \cdot 10^6$	> 10	K^-	Ni	non-exclusive 2026 1 year	
Prompt Photons (RF)	Meson gluon PDFs	≥ 100	$5 \cdot 10^6$	10-100	$K^\pm$ $\pi^\pm$	LH2, Ni	non-exclusive 2026 1-2 years	hodoscope
K-induced Spectroscopy (RF)	High-precision strange-meson spectrum	50-100	$5 \cdot 10^6$	25	K^-	LH2	2026 1 year	recoil TOF, forward PID
Vector mesons (RF)	Spin Density Matrix Elements	50-100	$5 \cdot 10^6$	10-100	$K^\pm, \pi^\pm$	from H to Pb	2026 1 year	

Table 2: Requirements for future programmes at the M2 beam line after 2021. Muon beams are in blue, conventional hadron beams in green, and RF-separated hadron beams in red.

Phase-1
with conventional
hadron and muon
beams
2022 → 2028

Phase-2
with conventional
and rf-separated
beams
2029 and beyond

The double polarized proton-proton interaction



Beam current 0.69 Ampere,
Luminosity is on the level of a few 10^{35}

Summary

The beams of EIC provide excellent opportunities for double polarized hadron physics experiments, e.g. with high intensity 18 GeV polarized electron beam.

They could be used for the fixed target experiments similar to HERMES with much higher productivity, also for the tagged photon beam and more.