Summary of WG7 "Future of DIS"

XIX International Workshop on Deep Inelastic Scattering and Related Subjects

April 11-15, 2011

Thanks to all our 46 speakers !!

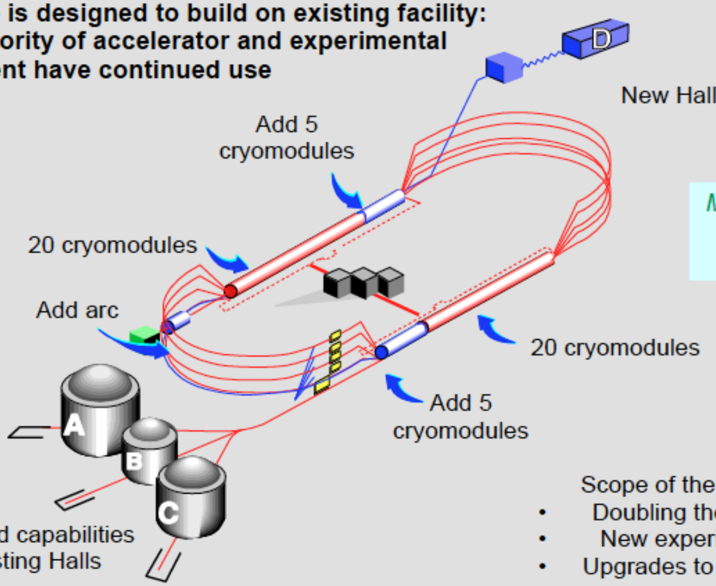
V. Guzey, M. Lamont, A. Polini

Project overviews: JLab12, EIC, LHeC

Jefferson Laboratory

12 GeV Upgrade Project

Upgrade is designed to build on existing facility: vast majority of accelerator and experimental equipment have continued use



Maintain capability to deliver lower pass beam energies: 2.2, 4.4, 6.6….

Scope of the approved project includes:
- Doubling the accelerator beam energy
- New experimental Hall and beamline
- Upgrades to existing Experimental Halls

See also plenary talk by R. Klanner

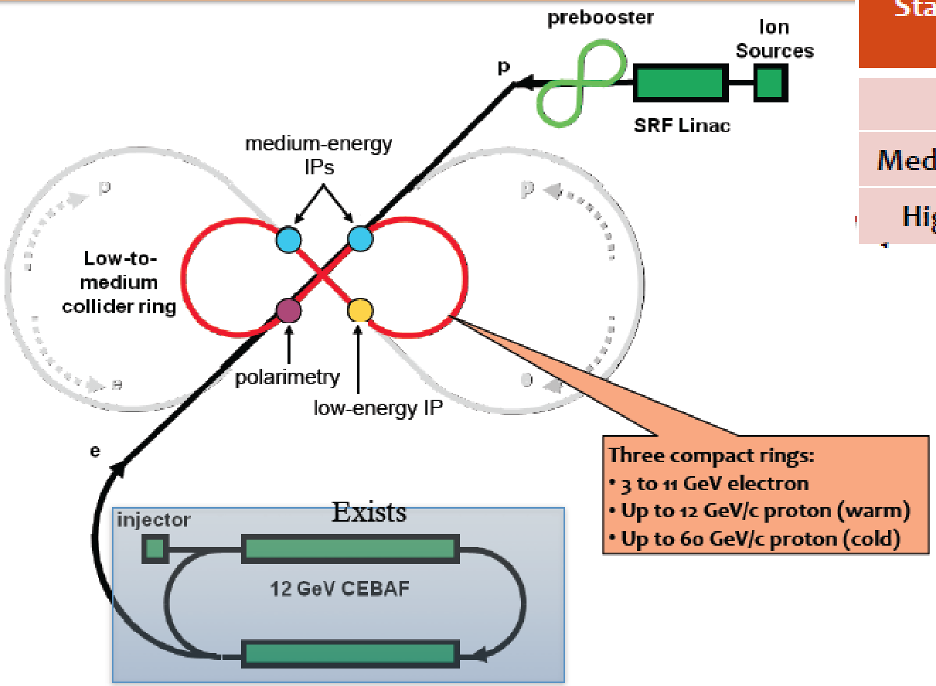
- First two cryomodules installed starting this May
- Major installation starting May 2012
- Accelerator and civil construction efforts approaching 70% complete
- Detector and spectrometer work underway now for Halls B, C, D; Hall A starts this October
- Hall A expects initial beam Oct 2013, Followed by Hall D in Apr 2014, and Halls C, B in Oct 2014
- 12 GeV Project complete June 2015

talk by G. Young

Project overviews: EIC

MEIC : Medium Energy EIC

Stage	Max. Energy (GeV/c)		Ring Size (m)	Ring Type		IP #
	p	e		p	e	
Medium	96	11	1000	Cold	Warm	3
High	250	20	2500	Cold	Warm	4

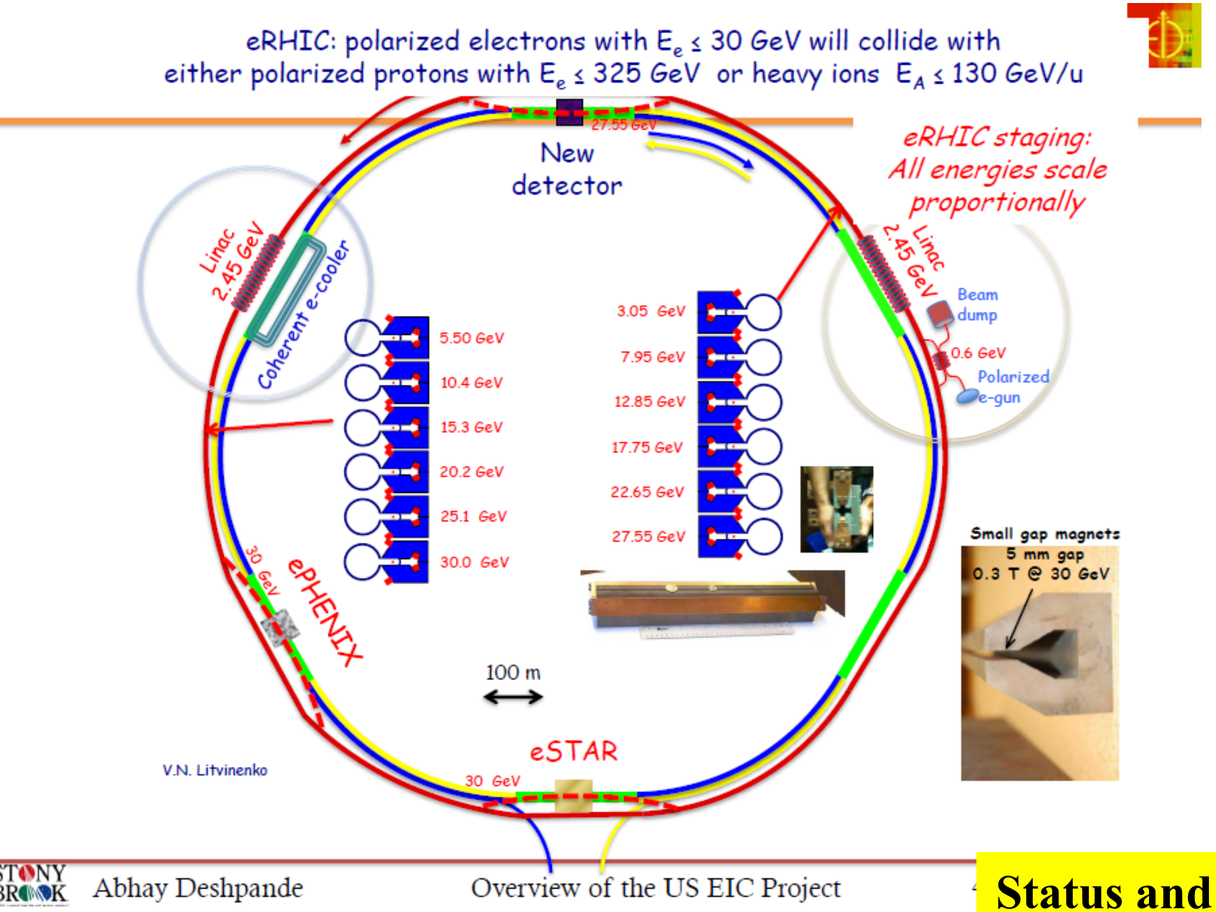


Abhay Deshpande Overview of the US EIC Project 4/12/2011 18

talk by A. Deshpande

Design status of medium-energy EIC at JLab talk by V. Morozov

Project overviews: EIC



Status and update on eRHIC project talk by V. Litvinenko

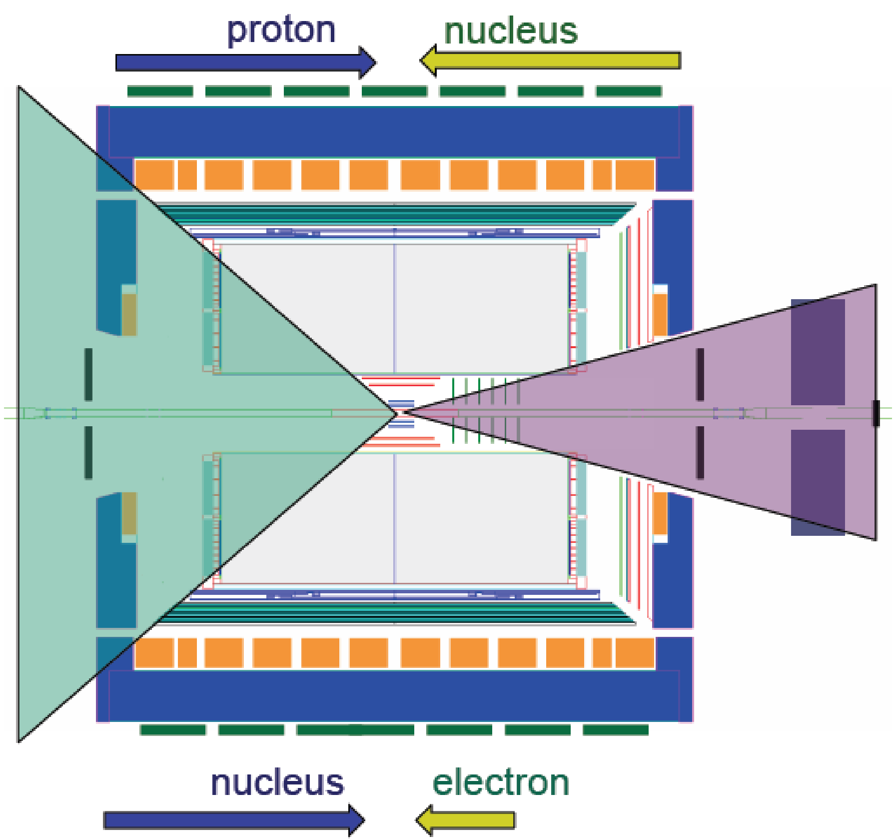
talk by A. Deshpande

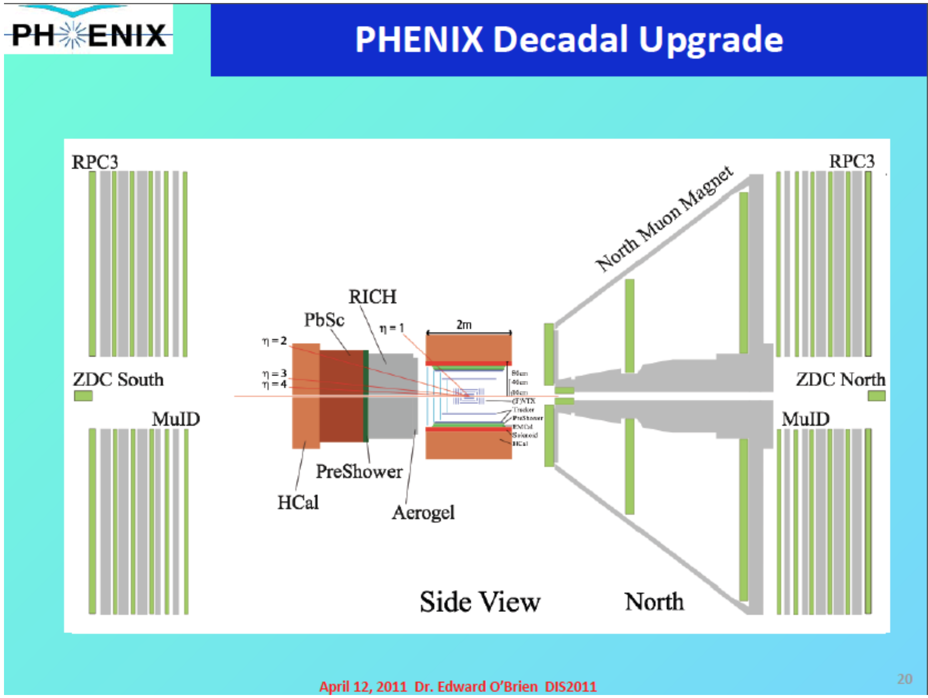
Main recent development: the JLab and BNL designs of EIC converge in energy, Lumi, and other paramet's

Project overviews: EIC

Building a new detector for EIC from scratch is expensive. BNL has explored the possibility of using the existing STAR and PHENIX detectors

STAR forward upgrade





talk by J. Dunlop

talk by E. O'Brien

Project overviews: LHeC

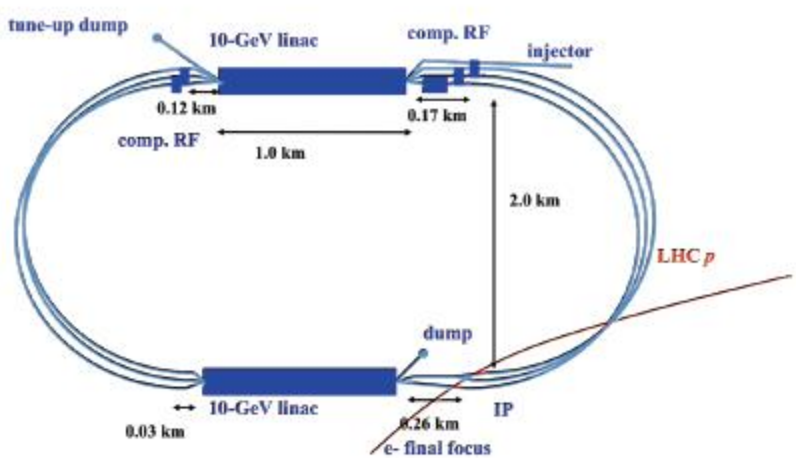
talk by M. Klein

LHeC: $e^{\pm}p/A$
E_e=10...140 GeV
E_p=1..7 TeV
$E_A=E_p$ *Z/A
L=$10^{33}cm^{-2}s^{-1}$
while LHC runs

	Electrons	Protons
Energy	60 GeV	7 TeV
Current	100 mA	860 mA
Part. per bunch	2×10^{10}	1.7×10^{11}
Numb. of bunches	2808	2808
$\varepsilon_x / \varepsilon_y$	5.0 / 2.5 nm	0.5 / 0.5 nm
P_γ	< 50 MW	

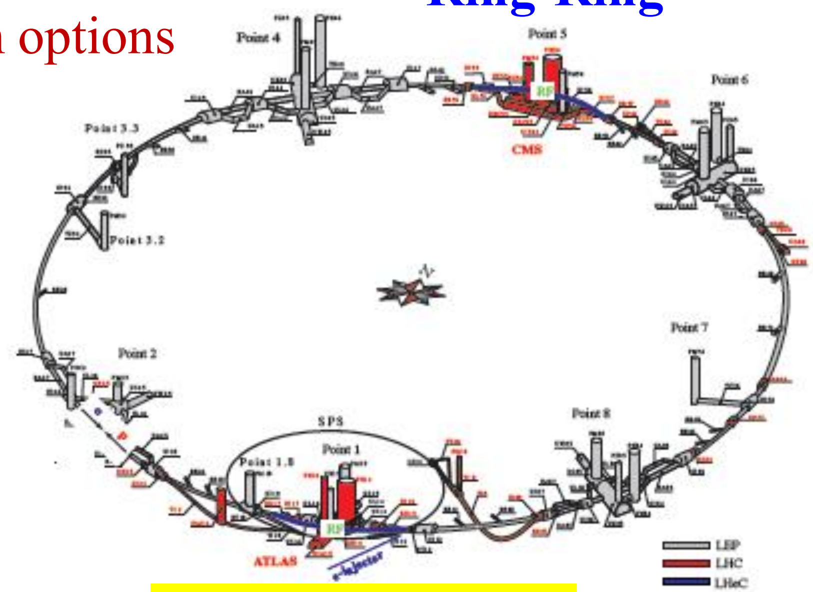
LHeC design options

Linac-Ring



talk by A. Bogacz

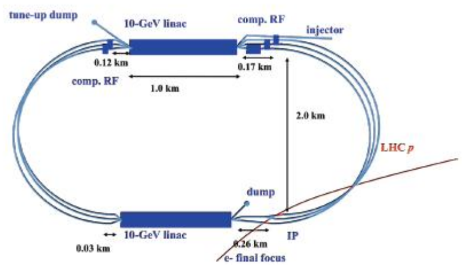
Ring-Ring

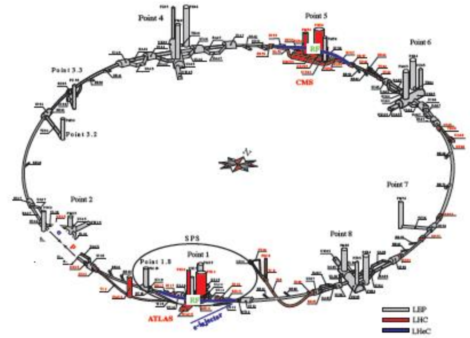


talk by M. Fitterer

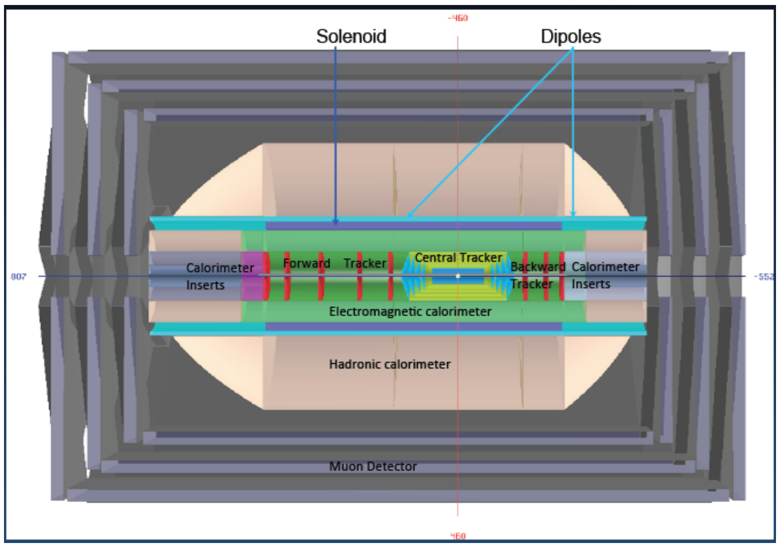
Project overviews: LHeC

Linac-Ring





Ring-Ring

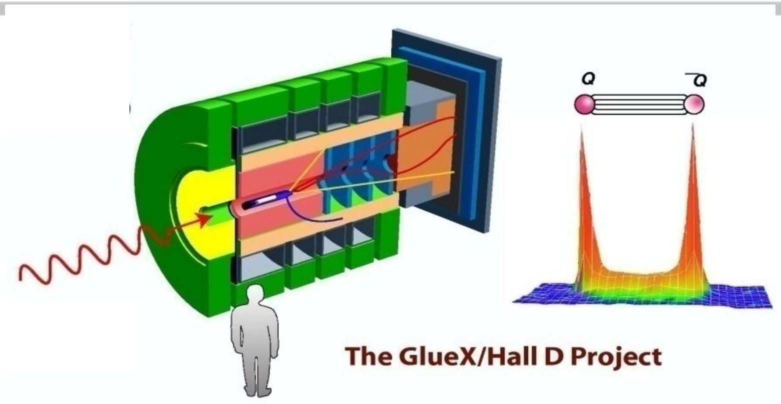


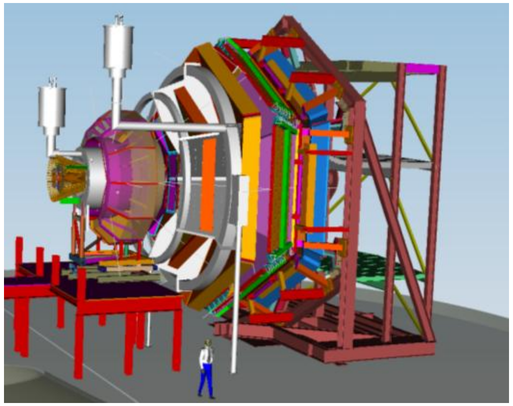
talk by P. Kostka: A detector design for LHeC

Conceptual Design Report on machine, detector, physics, 2011

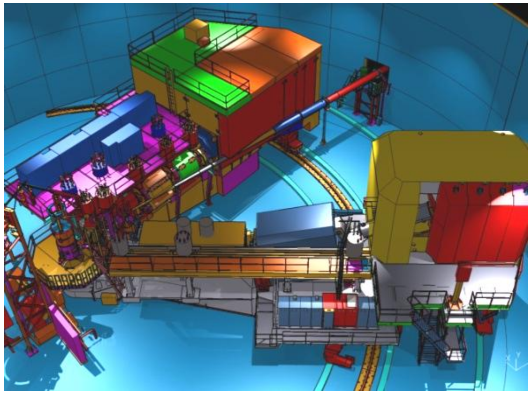
JLab12 Scientific Capabilities

Hall D – exploring origin of confinement by studying exotic mesons

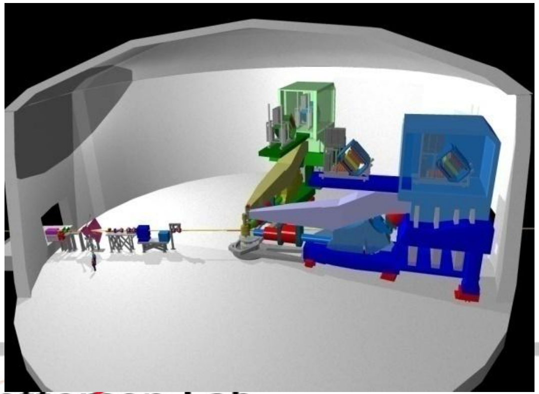




Hall B – understanding nucleon structure via generalized parton distributions



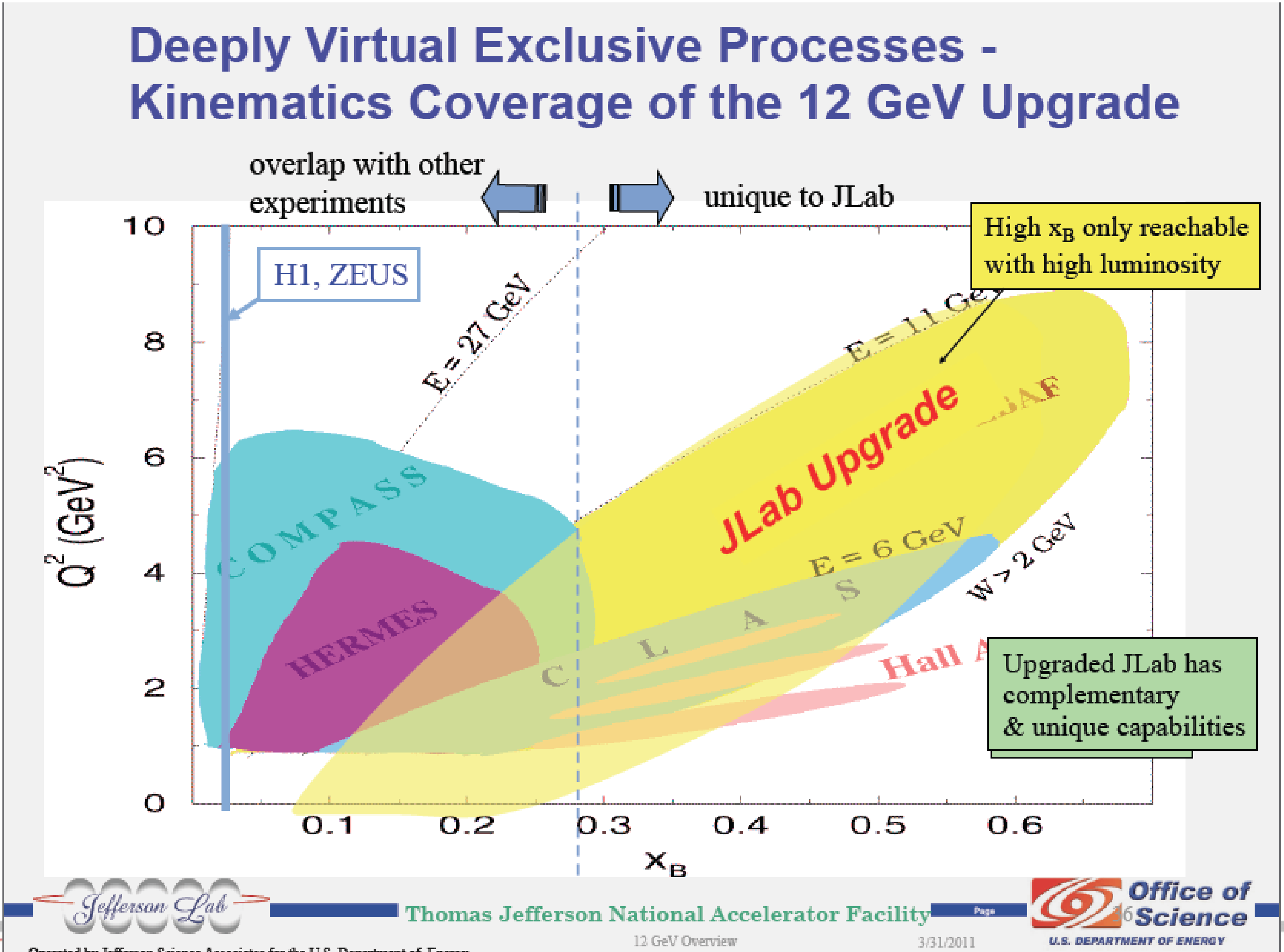
Hall C – precision determination of valence quark properties in nucleons and nuclei



Hall A – short range correlations, form factors, hyper-nuclear physics, new experiments (e.g. PV and Moller)

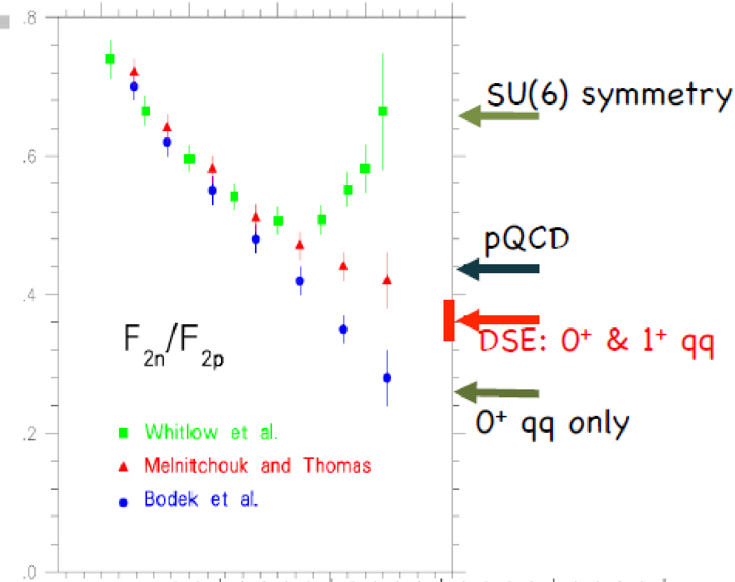
talk by G. Young

JLab12: machine for valence quarks



JLab12: d/u at large x

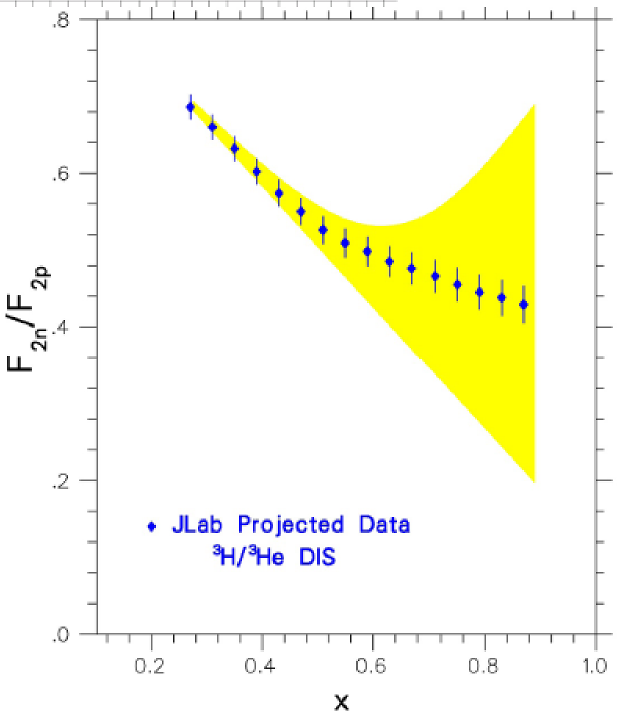
The ratio of d/u quark distributions (F_{2n}/F_{2p}) at large x > 0.6 is uncertain due to theoretical ambiguity in treatment of nuclear corrections (F_{2n} extracted from deuteron data)



Measurement of DIS off mirror nuclei (^3He and ^3H) will dramatically reduce uncertainty:

$$R(^3He) = \frac{F_2^{^3He}}{2F_2^p + F_2^n} \qquad R(^3H) = \frac{F_2^{^3H}}{F_2^p + 2F_2^n} \qquad R^* = \frac{R(^3He)}{R(^3H)}$$

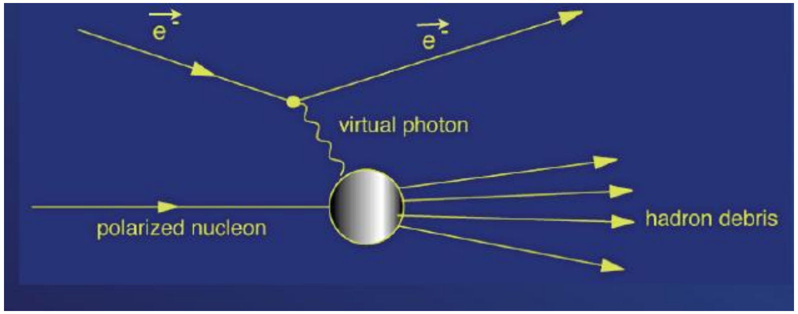
$$\frac{F_2^n}{F_2^p} = \frac{2R^* - F_2^{^3He}/F_2^{^3H}}{2F_2^{^3He}/F_2^{^3H} - R^*}$$



R* deviates from unity by ~1.5%, under good theory control

talk by J. Gomez (Jlab Hall A Marathon Collab.)

JLab12: A1n at large x

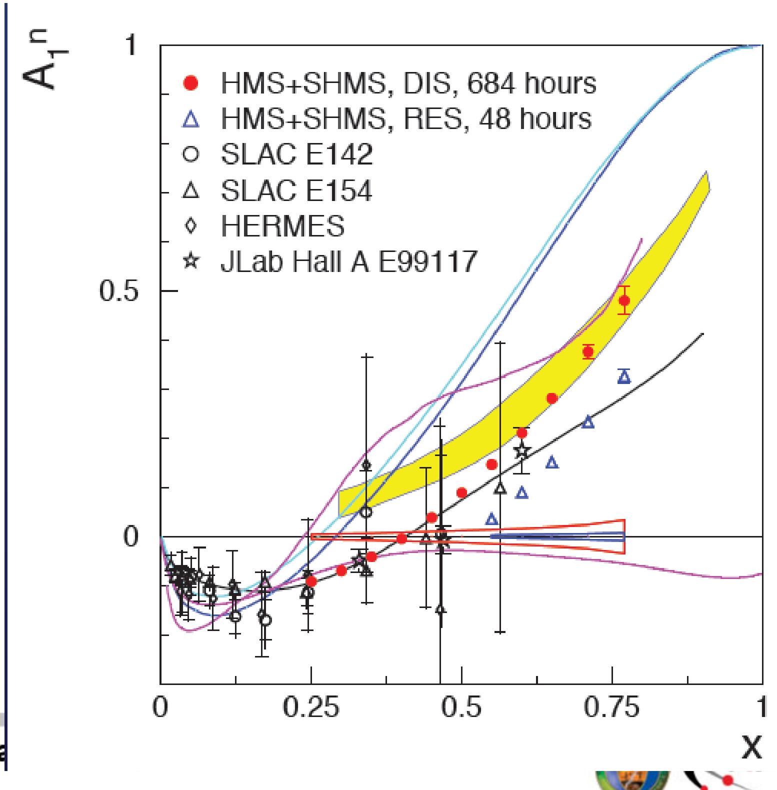


$$A_1^n = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$$

- Hadron helicity conservation (HCC): A1n →1 as x→1
- but not in all approaches
- affects/measures Δq/q at large x and indirectly points at $L_z \neq 0$ Fock states in wave function

Measurements are challenging:
- need high $L=3\text{-}10\times10^{36}\text{cm}^{-2}\text{s}^{-1}$
- high polarization

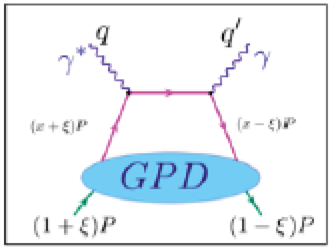
Hall A (BigBite)
Hall C (SHMS and HMS)

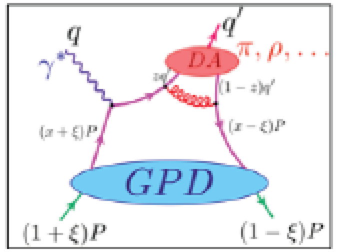


talk by G. Cates

JLab12: Generalized parton distributions for valence quarks

Only extensive measurements of different processes and observables and global analysis of data can disentangle and constrain generalized parton distributions (GPDs) .



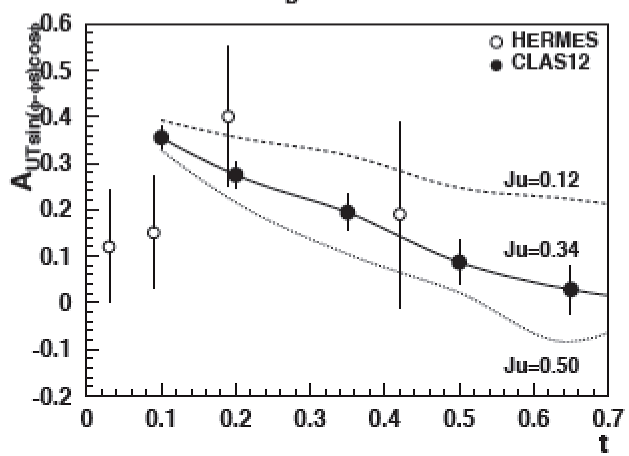


	$\mathcal{I}m$	$\mathcal{R}e$
$\mathcal{H}$	A_{LU}	σ , A_{LL}
$\tilde{\mathcal{H}}$	A_{UL}	
$\mathcal{E}$	A_{UT} , A_{LT}	

	Meson	Flavor
$\tilde{\mathcal{H}}, \tilde{\mathcal{E}}$	π^+	$\Delta u - \Delta d$
	π^0	$2\Delta u + \Delta d$
	η	$2\Delta u - \Delta d + 2\Delta s$
$\mathcal{H}, \mathcal{E}$	ρ^+	$u - d$
	ρ^0	$2u + d$
	ω	$2u - d$
	ϕ	s

DVCS with frozen HD-ice

$Q^2=2.6, x_B=0.25$



Example of simulations:

Transversely polarized → access to GPD E

→ enters spin sum rule

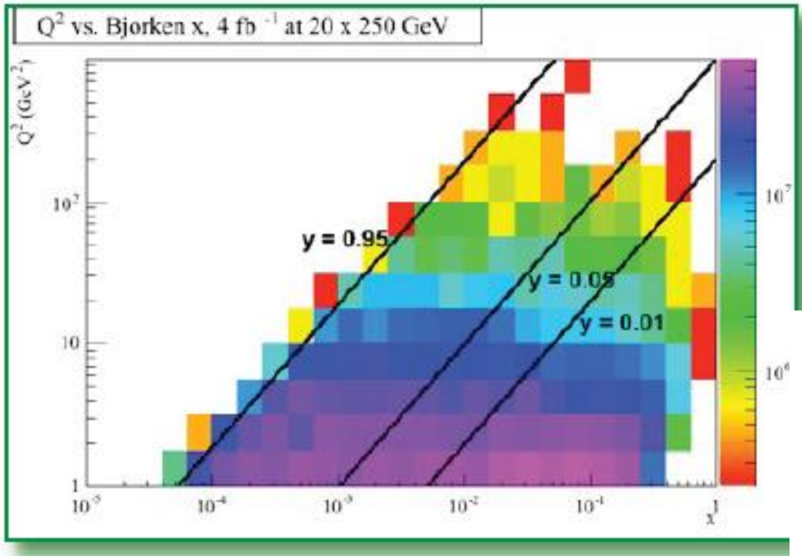
→ step towards tomography of valence quarks

talk by F.-X. Girod

All talks in JLab12 session

D. Gaskell	Semi-inclusive DIS in Hall C after the 12 GeV upgrade
X. Qian	SIDIS with polarized He-3 with SoLID at 11 GeV JLab
Y. Prok	Spin physics with CLAS12
J. Gomez	DIS off A=3 nuclei and the neutron to proton structure function ratio
F.-X. Girod	Generalized parton distributions with CLAS12
G. Cates	Measurement of the neutron spin asymmetry A1n at high Bjorken x after CEBAF upgrade

EIC: machine for sea quarks and gluons



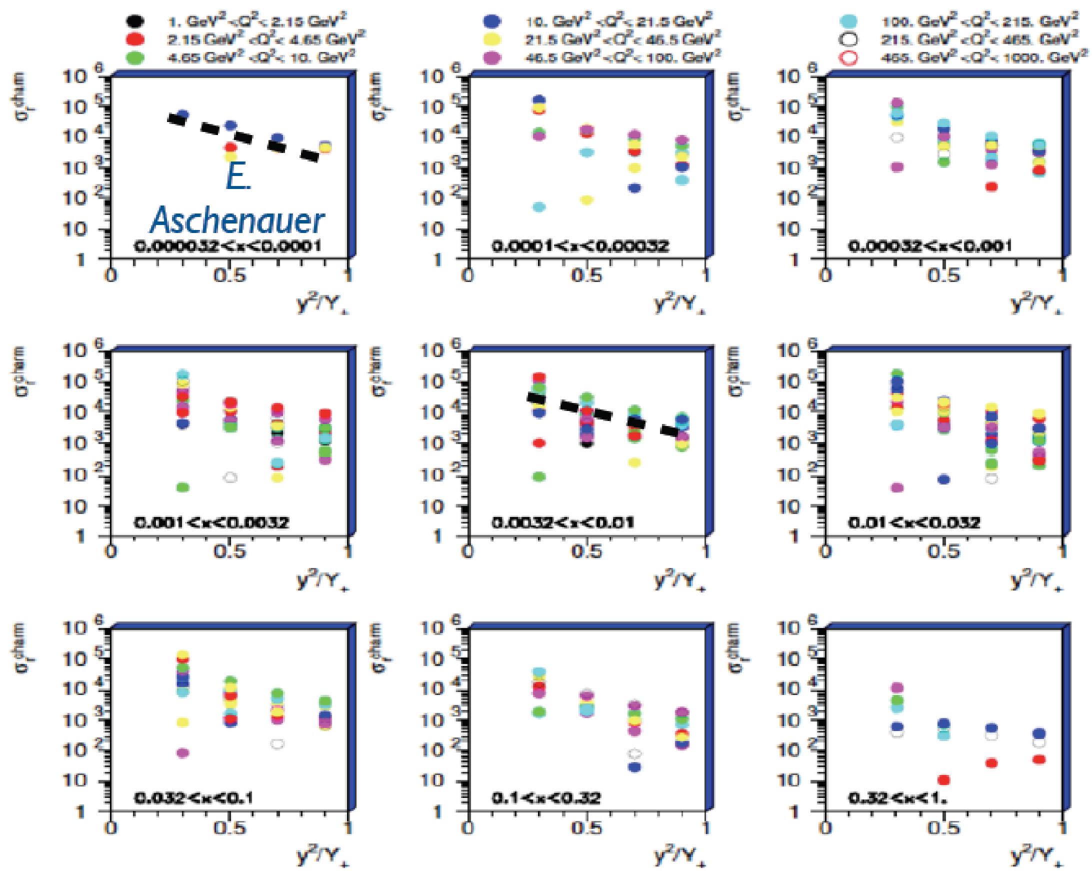
Several methods to measure gluon distribution at EIC:

- scaling violations of $F_2(x,Q^2)$
- longitudinal structure function F_L
- charmed $F_2{}^c$ and $F_L{}^c$

$$\sigma_r = F_2\left(x, Q^2\right) - \frac{y^2}{Y_+} F_L\left(x, Q^2\right)$$

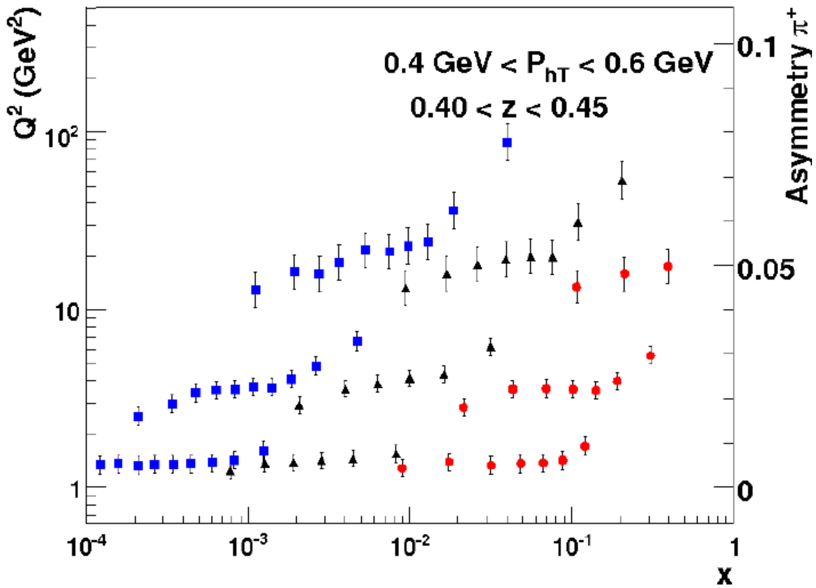
talk by T. Burton

With charm (D mesons)



EIC: accessing TMDs

Example of simulations of single-spin asymmetry in semi-inclusive DIS:



blue: 140 GeV, black 50 GeV, red 15 GeV, integrated lumi: 30 fb^{-1}

ion	Detected hadron	P_T region (divide @ 1GeV)	Luminosity (fb^{-1})
p	π	Low	30
n(^3He + D)	π	low	120
p	K	low	>3 x 30 (match with pion)
p	π	high	120
p	D	high	360 (multi-D binning, much fewer bins)
p	$D+\overline{D}$	high	Tens of 360 or high s?

DIS2011 - Min Huang

Similarly to the case of GPDs and exclusive reactions, the successful TMD program at EIC relies on:

- wide kinematic coverage (high P_T important for matching with twist-3 and moments of TMDs)
- high luminocity for 4D binning
- L & T polarizations of the hadron beam

talk by M. Huang

Also talks by J.Qiu and H. Gao

EIC: looking for saturation

Raison d'être for e+A

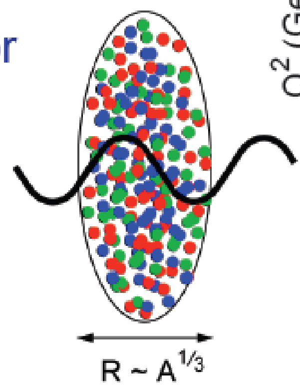
Scattering of electrons off nuclei:

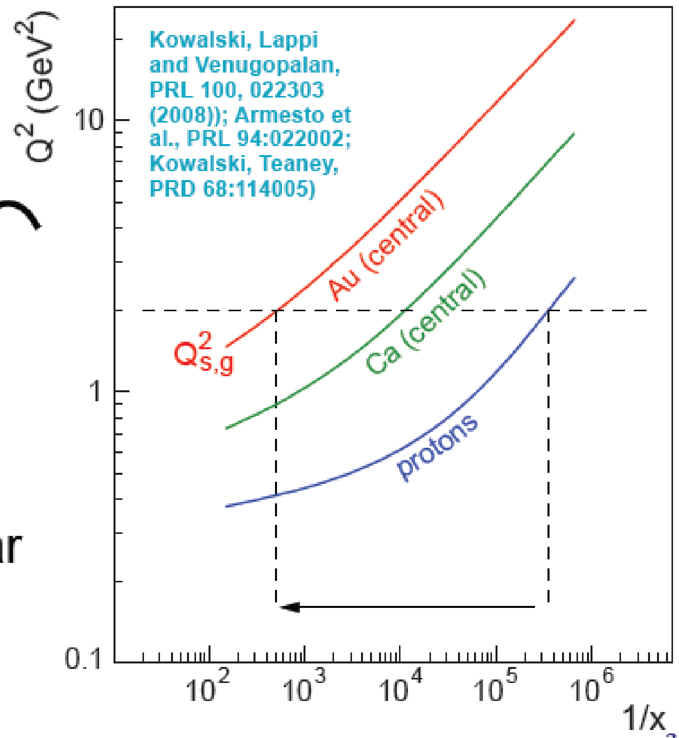
Probes interact over distances $L \sim (2m_N x)^{-1}$

For $L > 2\,R_A \sim A^{1/3}$ probe cannot distinguish between nucleons in front or back of nucleon ⇒ probe interacts *coherently* with all nucleons

"Expected"
Nuclear Enhancement Factor
(Pocket Formula):

$$(Q_s^A)^2 \approx c Q_0^2 \left(\frac{A}{x}\right)^{1/3}$$



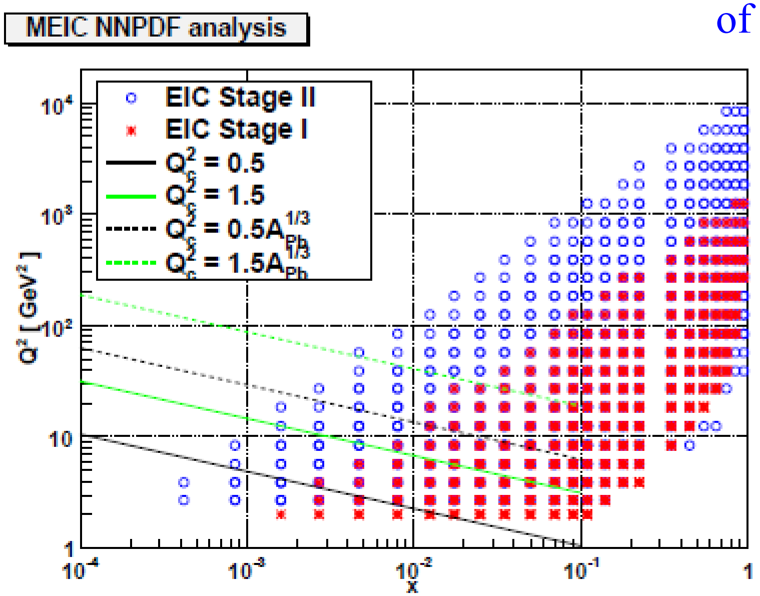


Enhancement of Q_S with A ⇒ non-linear QCD regime reached at significantly lower energy in A than in proton

talk by T. Ullrich

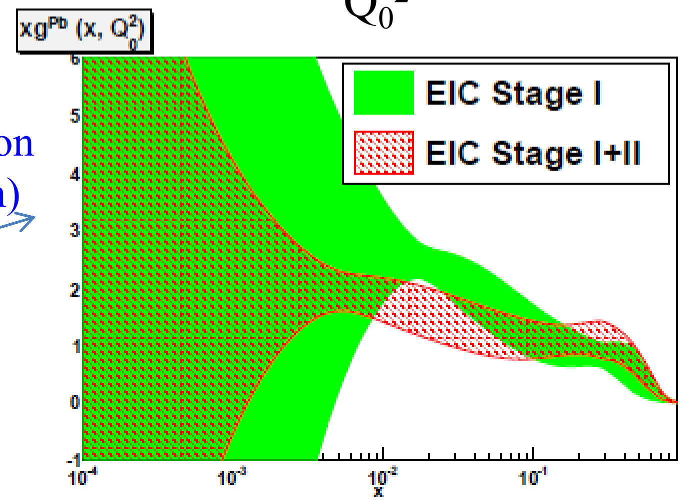
EIC: constraining nuclear gluons and search for saturation

Pseudo-data for total cross section for ^{208}Pb for EIC

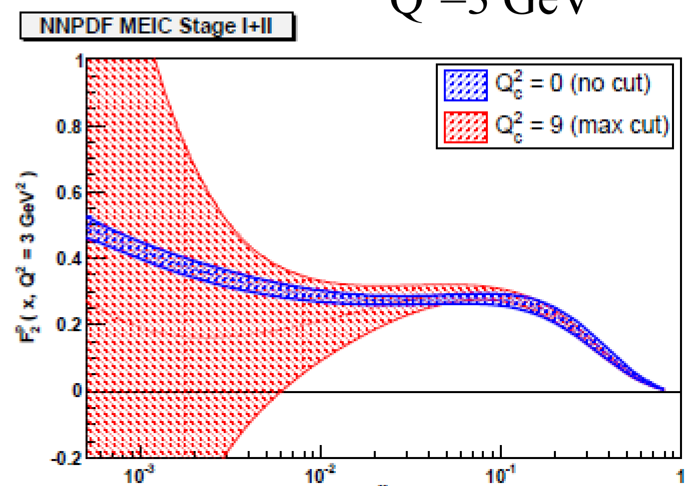


Neural Network determination of gluon PDFs (no saturation)

Q_0^2



Q^2=3 GeV^2



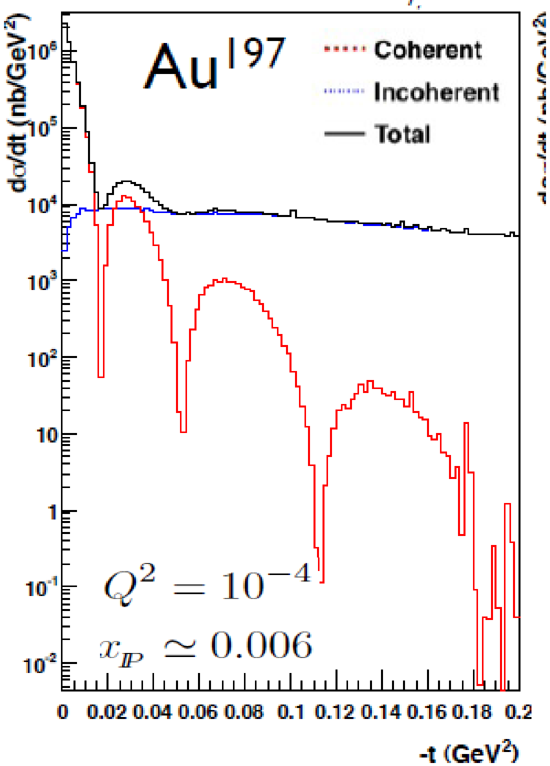
- Fit only data above Q_c^2
- Backward DGLAP evolution
- Systematic downward trend, consistent with non-linear effects

talk by J. Rojo

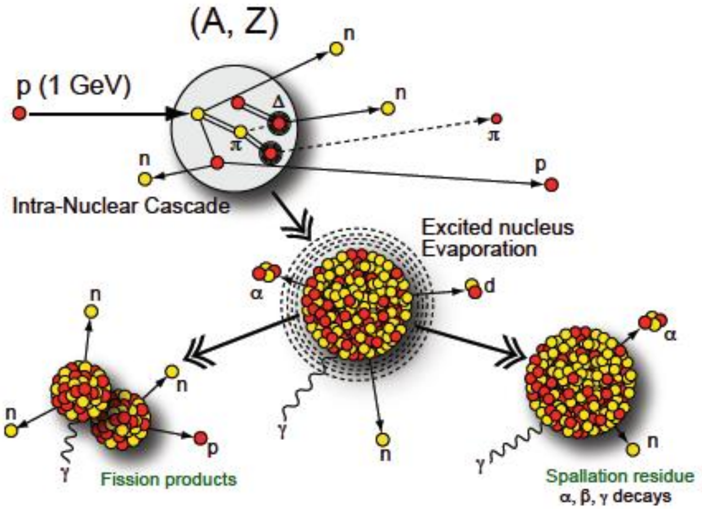
EIC: looking for onset of saturation in diffraction

- Diffraction is believed to be more sensitive to non-linear effects (saturation)
- New MC generator for e+A ("Sartre") : T. Ullrich and T. Toll
- Based on dipole model (b-Sat); checked against HERA J/ψ data
- Used both for transverse imaging of gluon distribution and search for onset of saturation

$$e + A \rightarrow e' + J/\Psi + A'$$



The important issued of huge incoherent "background" can be solved by Zero-Degree Calorimeter (detection of neutrons)



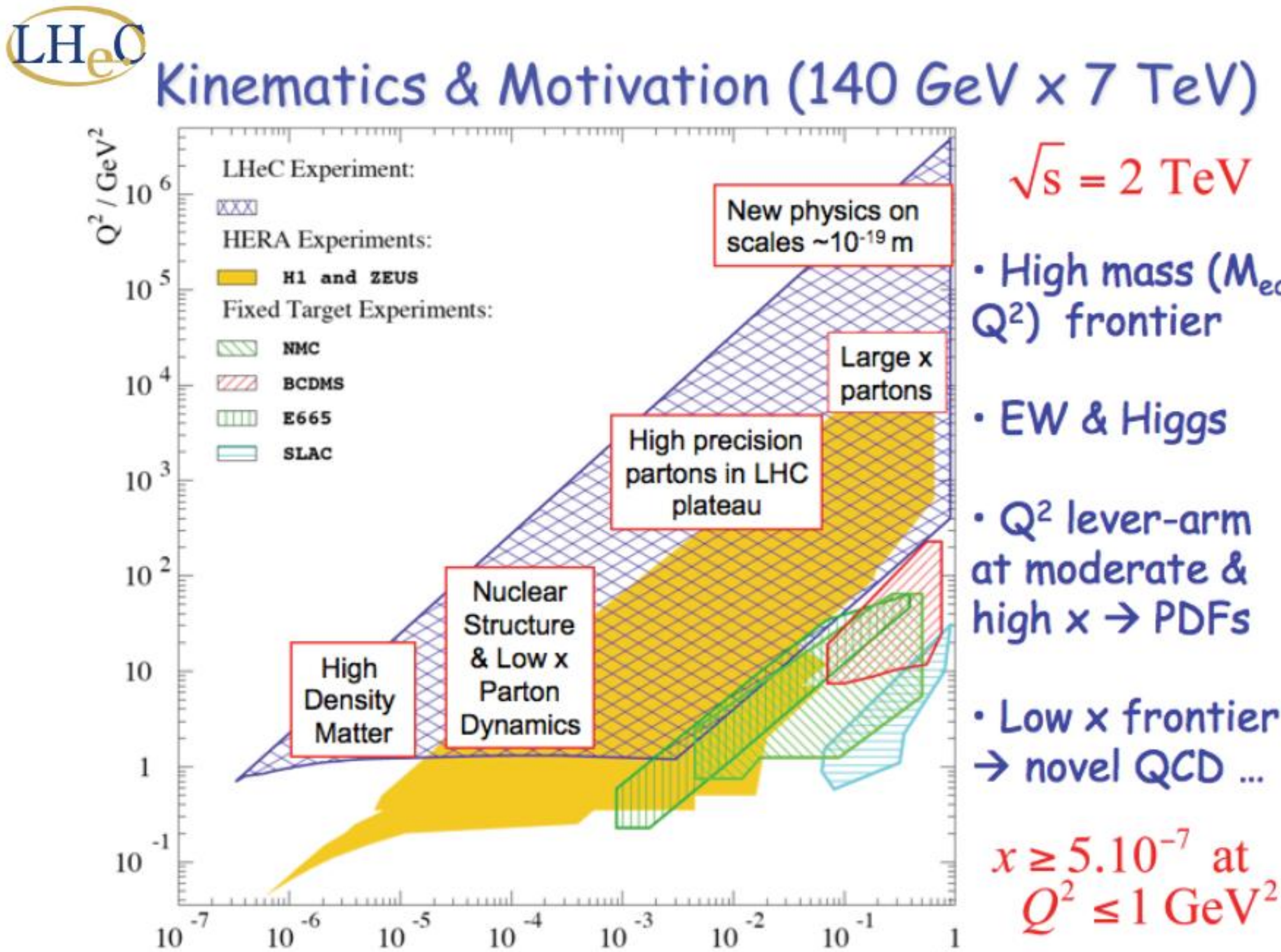
talk by T. Toll

talk by T. Ullrich

All EIC-related talks (in WG7)

An update on eRHIC acceleraor	*V. Litvinenko*
Design status of of MEIC at JLab	*V. Morozov*
PDFs today and tomorrow	*M. Stratmann*
Theory overview of e-A physics at the EIC	*J. Jalilian-Marian*
Experimental overview of e-A physics at the EIC	*T. Ullrich*
A new Monte Carlo event generator for eA collisions at low-x	*T. Toll*
Theory overview of e+p physics at an EIC	*J. Qiu*
Experimental overview of e+p physics at an EIC	*H. Gao*
Imaging sea quarks and gluons at the EIC	*T. Horn*
Ep physics opportunities at eRHIC	*T. Burton*
Transverse single-spin asymmetry measurement from SIDIS at an EIC	*M. Huang*
Studying the Sivers and Boer-Mulders functions with lattice QCD	*B. Musch*
Weak mixing angle measurement at EIC	*Y. Li*
PHENIX and STAR Detector Upgrades (for use as Stage 1 eRHIC detector)	*E. O'Brien, J. Dunlop*

LHeC: The ultimate energy frontier

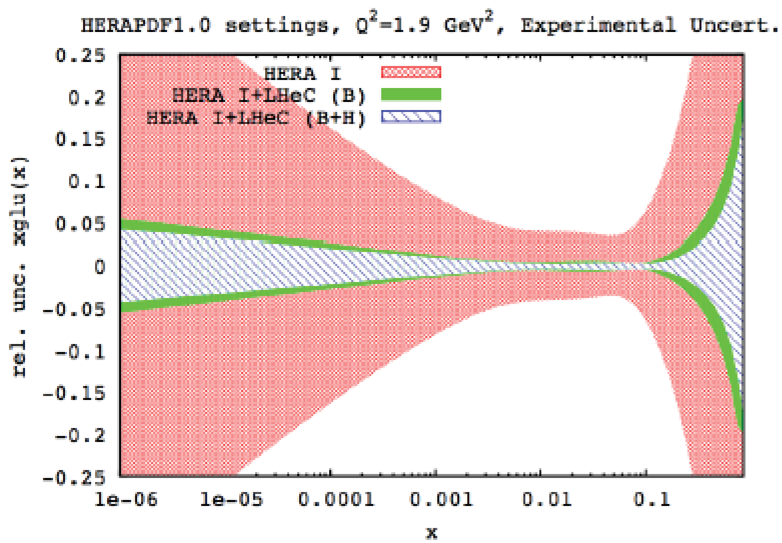


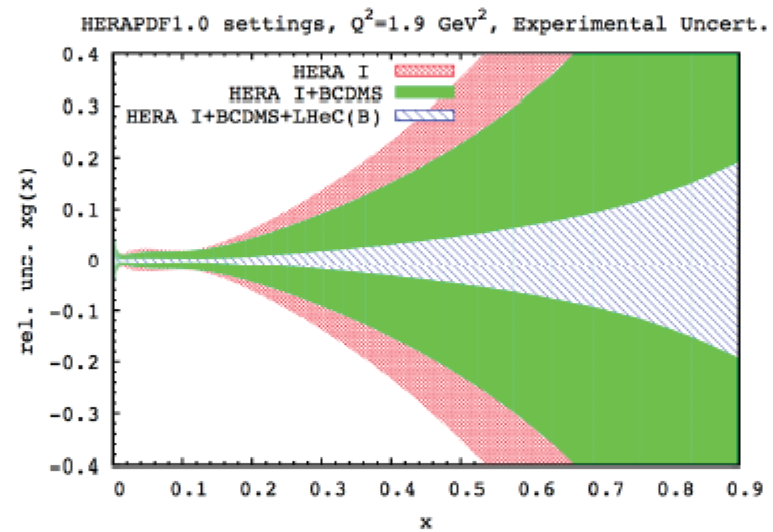
talk by A. Stasto

LHeC: constraining proton PDFs

Impact of LHeC on PDFs: gluon

* Experimental uncertainties are shown at the starting scale $Q^2=1.9\ GeV^2$





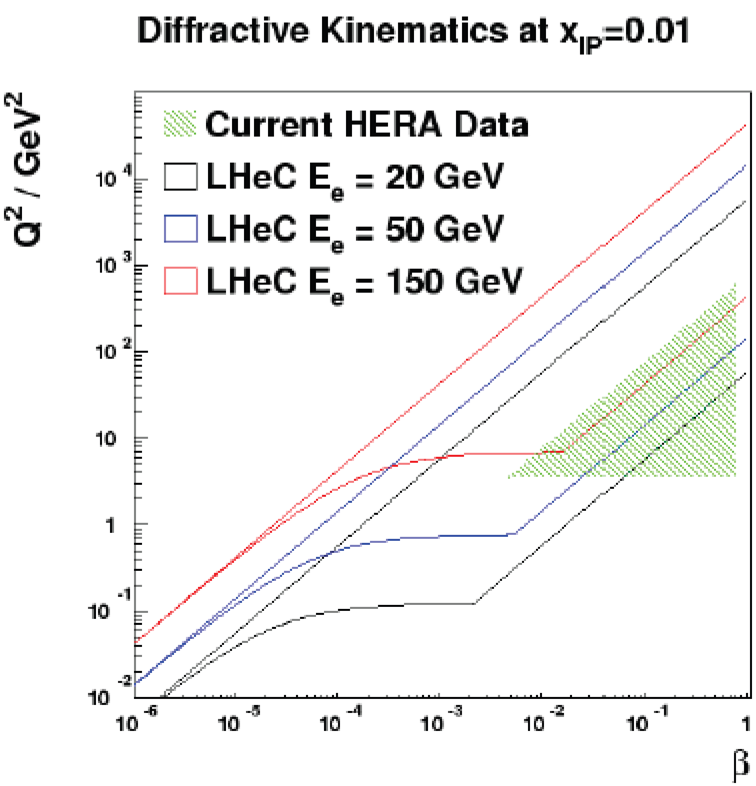
- Based on simulated data, impressive capability for LHeC to constrain gluon:
  - At low and high x

- **Similar impressive precision for quarks of different flavors → flavor separation "for free"**
- **LHeC will also provide constraints on nuclear PDFs**

talk by V. Radescu

LHeC: Inclusive diffraction in novel kinematics

Many possible measurements of diffraction (inclusive, exclusive) in previously inaccessible kinematics → expect surprises (remember HERA !)



- Large lever arm in Q^2 for global fits of diffractive PDFs
  → reliable predictions for nuclear shadowing in nuclear PDFs (Gribov-Glauber connection)

- Small β → triple-Pomeron limit of large diffractive masses → legitimate region of non-linear effects (saturation)

- Also diffraction with nuclei

talk by P. Newman

All Talks in LHeC session

M. Klein	Overview of the LHeC project
A. Bogacz	LHeC Linac-Ring design
M. Fitterer	LHeC Ring-Ring design
P. Kostka	A detector for the LHeC
A. Stasto	Low-x physics at the LHeC from inclusive measurements
P. Newman	Low-x physics at the LHeC from exclusive measurements
B. Cole	e+A physics with the LHeC
V. Radescu	QCD analysis at the LHeC
O. Behnke	Heavy flavors at the LHeC
U. Klein	LHeC beyond the Standard Model

Other contributions to “Future of DIS” WG

- ❑ Neutrino DIS at MINERvA**, J. Mousseu**

Measurement of nuclear modifications (shadowing, EMC) in neutrino DIS; some analyses of NuTeV indicate difference from eA DIS

- ❑ The Olympus experiment at DESY**, M. Kohl**

Two-photon exchange contribution in e^+/e^- p elastic scattering

- ❑ AnDY: overview and plans**, C. Perkins**

Measurement of transverse single-spin asymmetry in jet production in Drell-Yan and verification of sign change of Siverse function w.r.t. SIDIS

- ❑ Compass 2 program and Polarized Drell-Yan at Compass**, C. Quintans**

160 GeV mu-beam on L and T stationary target: strange quark PDF, GPDs and TMDs (in DY)

- ❑ ATLAS upgrades for the HL-LHC and the Physics Case**, S. Demers**

Summary

The future DIS facilities – JLab12, Compass-2 at CERN, EIC, and LHeC -- as well as progress in theory will help up to unravel the internal structure of the nucleon and nuclei in terms of quarks and gluons and better understand their dynamics.

In particular, we should be able to make progress in the following areas:

- Mapping out the spin and spatial structure of quarks and gluons in nucleons
- Discovering the collective effects of gluons in atomic nuclei
- Understanding the emergence of hadronic matter from quarks and gluons