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Overview of Inclusive Physics on EicC

Preparation for the Draft of EicC CDR

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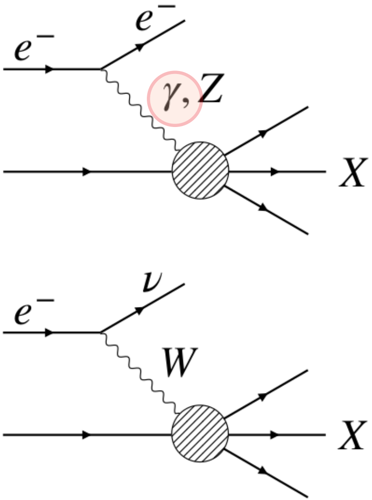
Outline

Kinematics of Inclusive Process

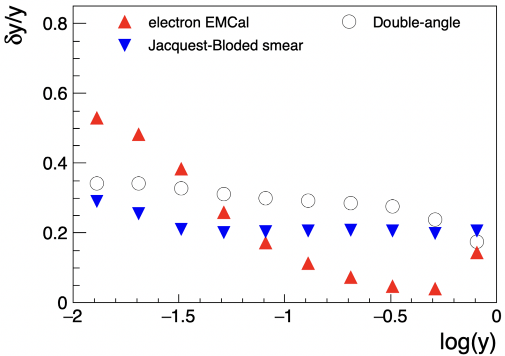


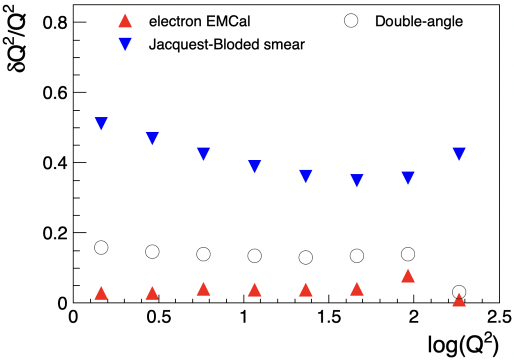
$$Q^2 = 4EE' \cos^2\left(\theta_p^{e'}/2\right), \quad y = 1 - \frac{E'\left(1-\cos\theta_p^{e'}\right)}{2E}, \quad x = \frac{Q^2}{sy},$$

$$Q^2_{JB} = \frac{p_T^2}{1-y_{JB}}, y_{JB} = \frac{\sum_h (E-p_z)}{2E}, \quad x = \frac{Q^2_{JB}}{sy_{JB}},$$

- DIS variables (x, Q^2 and y) of kinematic reconstruction are essential for all physics processes,
- Reconstruction from scattering electron or hadronic final state,
- Only possible for CC processes with reconstruction from hadronic final state,
- Deep Learning might be considered [Eur. Phys. J. C (2022) 82:1064].

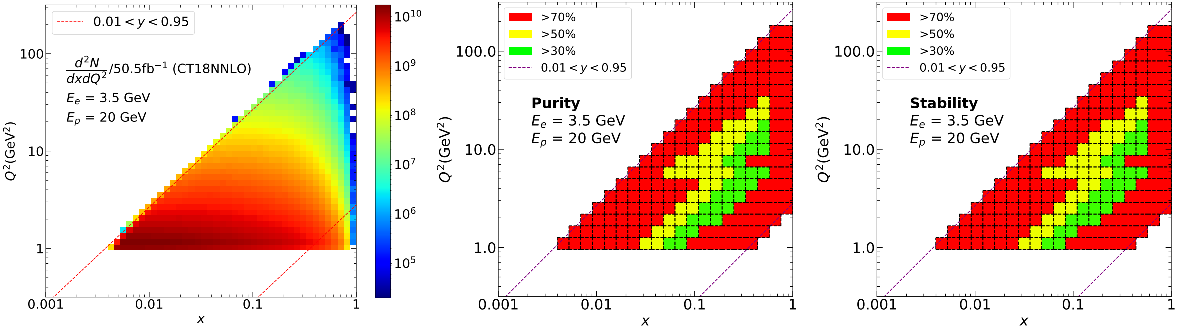
Inclusive Measurements on EicC





- Polar angle θ smearing: $0.2/\sqrt{E(\text{GeV})}$ rad and $0.4/\sqrt{E(\text{GeV})}$ rad for the two endcap regions and barrel regions, respectively,
- Energy resolution from Ecal: $2.5\%/\sqrt{E(\text{GeV})}$ for the $e-$endcap, $5\%/\sqrt{E(\text{GeV})}$ for the barrel and $h-$endcap,

Inclusive DIS on EicC



- Significant PDF constraints through precision QCD measurements in the quark-hadron transition region,
- Purity and stability in a given kinematic bin by considering the resolution of EicC detector.

Theoretic Calculation and Psuedo-Data

Particle	Momentum (GeV/c/u)	Integrated luminosity (fb^{-1})	N_{pt}	Uncor. Unc. of Opt. (Con.)	Cor. Unc. of Opt. (Con.)
p	20	50.5	73	1.5% (2.3%)	2.5% (4.3%)
D	12.9	21.4	51	1.5% (2.3%)	2.5% (4.3%)

Particle	Momentum (GeV/c/u)	Integrated luminosity (fb^{-1})	N_{pt}	Uncor. Unc.	Cor. Unc.
$^{3}He^{++}$	17.21	15.9	51	1.5%	2.5%
$^{7}Li^{3+}$	11.05	24.6	51	1.5%	2.5%
$^{12}C^{6+}$	12.90	21.1	51	1.5%	2.5%
$^{40}Ca^{20+}$	12.90	21.1	51	1.5%	2.5%
$^{197}Au^{79+}$	10.35	23.6	51	1.5%	2.5%
$^{208}Pb^{82+}$	10.17	23.3	51	1.5%	2.5%

Kinematic region:

$W^2 > 12.25$ GeV^2

$Q^2 > 4$ GeV^2

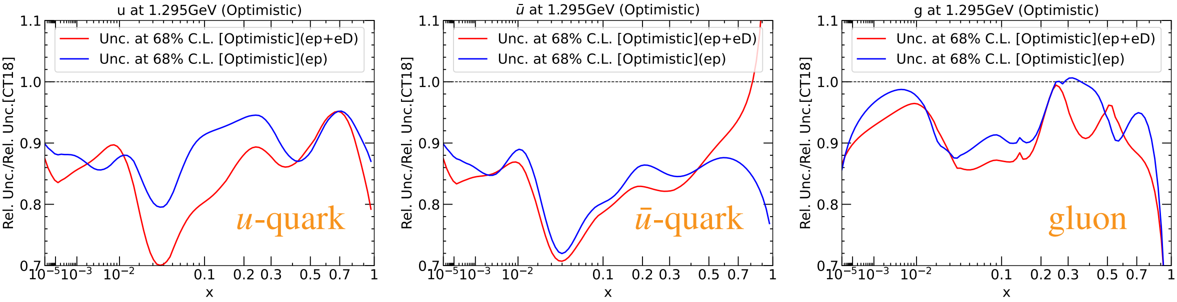
$0.01 < y < 0.95$

(pQCD)

Systematic Uncertainties: two scenario for ep and eD

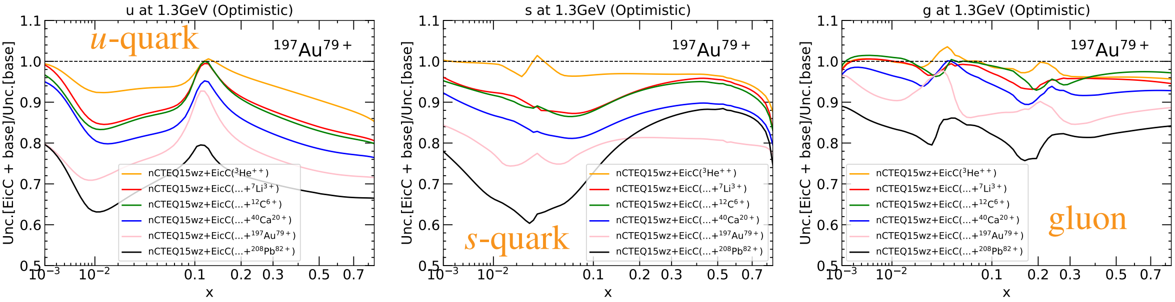
Theoretic predictions on inclusive DIS cross section computed at NNLO in QCD with the SOCAT-χ scheme.

Impact on PDFs



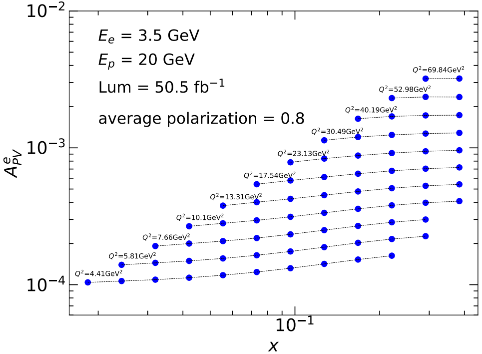
- Based on the CT18 NNLO baseline PDFs and the EicC pseudo-data,
- Results for Q = 1.295 GeV, PDFs for other components also included in CDR draft,
- PDF uncertainties generally reduced by about 10% (15%), comparable to EIC studies,
- Depends on the assumption of systematic uncertainties.

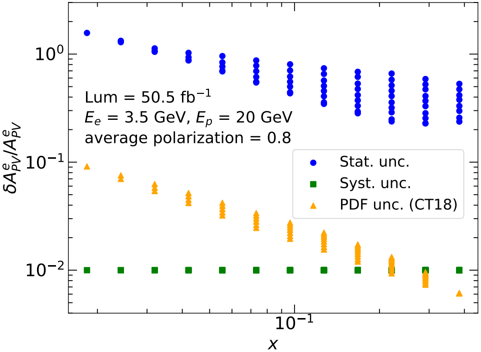
Impact on Nuclear PDFs (nPFDs)



- Based on the nCTEQ15WZ NLO baseline nPDFs and the EicC pseudo-data,
- Results for Q = 1.3 GeV, PDFs for other components also included in CDR draft,
- Uncertainties of quark nPDFs reduced by about 20%,
- Depends on the assumption of systematic uncertainties.

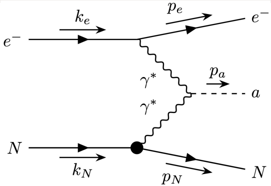
Singe Spin Asymmetry

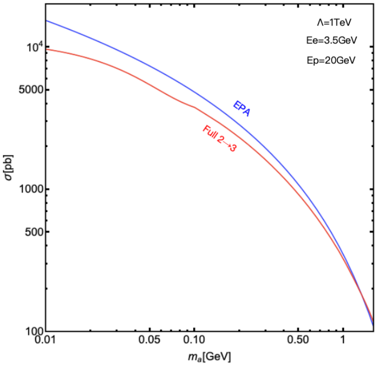




- Single spin asymmetry: $A^e_{PV} = \frac{\sigma^{e\uparrow} - \sigma^{e\downarrow}}{\sigma^{e\uparrow} + \sigma^{e\downarrow}}$,
- Highly suppressed at EicC due to the low cms energy.
- δA^e_{PV}(PDF)$\sim$ 5% and δA^e_{PV}(stat.)$\sim$ 50%

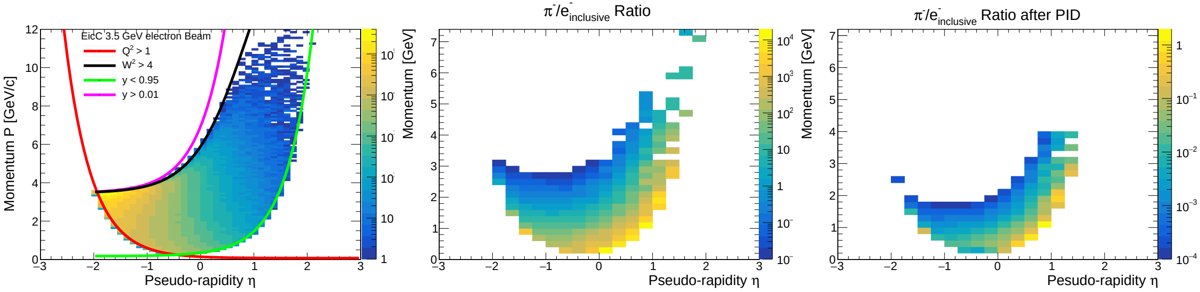
Axion-Like Particle at EicC





- Axion-Like particle (ALP) produced at EicC through photon fusion process,
- Maximum ALP mass:
  $$(m_a)_{\max} \sim 5 \text{ GeV} \left(\frac{E_e}{3.5 \text{ GeV}}\right)^{1/2} \left(\frac{E_N/A}{20 \text{ GeV}}\right)^{1/2} \left(\frac{A}{207}\right)^{-1/6},$$
- Preliminary study shows that EicC have a good ability to detect ALP (see details in Hongkai's talk),
- Other NP topics, dark photon and PV asymmetry in the SMEFT, are discussed in CDR draft and are under the investigation.

Requirements to Detector from Inclusive Measurements



- Kinematic region of scattering electron, $-2 < \eta < 2$, covered by EicC detector,
- Momentum of scattering electron ranged from 0.2 GeV up to 12 GeV,
- High pion background for low momentum and ion forward η,
- High e/π separation power is desired, $10^4 - 10^5$,
- Need to combine the PID information from several sub-detectors.

Preparation on CDR write-up

Contents

- The draft of inclusive physics is in a good shape for the CDR,
- Topics of New Physics are under investigation.


thank you
gracias
danke
merci
obrigado
謝謝
teşekkür ederim
ngiyabonga
go raibh maith agat
mochchakkeram
dziękuję
sukriya
kop khun krap
terima kasih
bedankt
спасибо
grazie
arigatô
dakujem
мерси
감사합니다
ありがとう
dank je
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Backup

Systematical Uncertainties on EIC

Systematic uncertainties for the inclusive pseudo-data

As the uncertainties on the NC inclusive cross section measurements at the EIC will be dominated by systematic errors for much of the probed kinematic phase space, it is necessary to make estimates of those errors for the generated pseudo-data. For the CC inclusive cross section measurements the systematic uncertainty will most likely be at a similar level as the statistical uncertainty for much of the measured kinematic phase space. Although it is very difficult to determine systematic uncertainties for an accelerator and detector which have not yet been constructed, estimates of these uncertainties can be made based on the experience of previous experiments (primarily those at HERA) as well as simulation studies using the EIC Handbook detector and the current EIC detector matrix.

The systematic uncertainties on the pseudo-data were divided into uncorrelated uncertainties (i.e. point-to-point or bin-by-bin uncertainties) and scale uncertainties (i.e. normalization uncertainties). No attempt was made to estimate partially correlated systematic uncertainties. Two sets of systematic uncertainties were constructed: an optimistic set and a conservative set.

For the unpolarized NC electron(positron)-proton cross section measurements, the estimate of the uncorrelated uncertainty was 1.5% (2.3%) in the optimistic (conservative) scenario. These uncertainties came from a 1% uncertainty on the radiative corrections; and a 1-2% uncertainty due to detector effects. An additional uncertainty of 2% was added for the pseudo-data with $y < 0.01$, as hadronic reconstruction methods are required in that kinematic region. The normalization uncertainty

was set at 2.5% (4.3%) in the optimistic (conservative) scenario. This included a 1% uncertainty on the integrated luminosity; and 2-4% uncertainty due to detector effects. During the fits of the pseudo-data, the normalization uncertainty was treated as fully correlated between different beam energy settings.

The same uncertainties were used for the unpolarized NC electron-nucleus cross section measurements, with the exception that data at $y < 0.01$ was not included for the e-A pseudo-data sets.

Kinematics Reconstruction with DNN

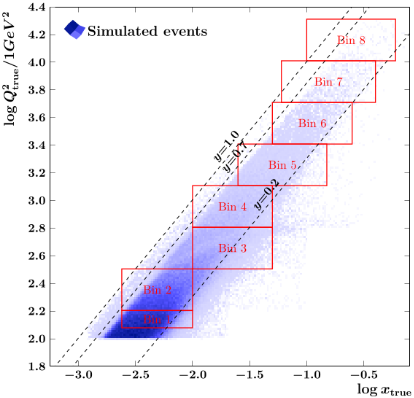

Table 4 Resolution of the reconstructed kinematic variables in bins of x and Q^2. The resolution for x and Q^2 is defined as the RMS of the distributions $\log(x) - \log(x_{true})$ and $\log(Q^2) - \log(Q^2_{true})$ respectively

Bin	Events	Resolution of $\log x$		Resolution of $\log Q^2/1\,\mathrm{GeV}^2$	
1	301780	**NN: 0.070**	EL: 0.083	**NN: 0.035**	EL: 0.035
		JB: 0.180	DA: 0.103	JB: 0.203	DA: 0.062
2	350530	**NN: 0.069**	EL: 0.082	**NN: 0.040**	EL: 0.043
		JB: 0.167	DA: 0.096	JB: 0.192	DA: 0.064
3	138456	**NN: 0.098**	EL: 0.130	NN: 0.055	**EL: 0.053**
		JB: 0.138	DA: 0.100	JB: 0.150	DA: 0.077
4	74844	**NN: 0.067**	EL: 0.084	**NN: 0.044**	EL: 0.046
		JB: 0.117	DA: 0.077	JB: 0.138	DA: 0.063
5	31043	**NN: 0.064**	EL: 0.091	**NN: 0.036**	EL: 0.041
		JB: 0.102	DA: 0.073	JB: 0.117	DA: 0.053
6	11475	**NN: 0.053**	EL: 0.079	**NN: 0.033**	EL: 0.036
		JB: 0.083	DA: 0.061	JB: 0.100	DA: 0.045
7	3454	**NN: 0.050**	EL: 0.069	**NN: 0.036**	EL: 0.038
		JB: 0.074	DA: 0.055	JB: 0.093	DA: 0.042
8	624	**NN: 0.036**	EL: 0.055	**NN: 0.033**	EL: 0.037
		JB: 0.067	DA: 0.045	JB: 0.095	DA: 0.041

Minimal value shown in bold

- Deeply learning deep inelastic scattering kinematics [Eur. Phys. J. C (2022) 82:1064],
- Train DNN by using simulated data from ZEUS experiment at HERA,
- Feasible study might be considered with similar approach on EicC.