

# ePIC - Italia General Meeting

26 September 2024

## Early Physics Workshop : outcomes and next steps



**Marco Radici**

# Motivation

- EICUG-ePIC meeting, July 22-28: presentation by Elke with proposal for Early Science Program (CD4 < Year 1,2..)
- EIC Project Strategy workshop, Aug. 21: revised version after discussions, linked on Indico page (next slide)
- ePIC Early Science workshop, Sept. 13: open discussion in order to define a **meaningful** and **impactful** early science program
- **planning goal:** deliver science **within 10 years** from RHIC shutdown (2025)
- **Phase-I Physics:** start of promised NSAC/NAS science program alignment with order in commissioning the collider having new physics results early to get impact papers



# The program











## ePIC Early Science Workshop

Friday 13 Sept 2024, 10:30 → 13:30 US/Eastern

**Description** Connection Information: <https://www.zoomgov.com/j/16028186096?pwd=dndBRnBF5kxkN3RlThNLZlRlTjZKQT09>

Recording: <https://youtu.be/Cd0gvc1-T9k>

 Early.Physics.eca.L...  Early.Physics.eca.v...

10:30 → 10:45	<b>Introduction and Overview</b>	15m
Speakers: John Lajoie (Oak Ridge National Laboratory), Silvia Dalla Torre (INFN, Trieste)		
 ePIC Collaboration ...		
10:45 → 11:15	<b>The Phase-1 Electron-Ion Collider</b>	30m
Speaker: Sergei Nagaitsev		
 SNagaitsev_091324...		
11:15 → 11:30	<b>Inclusive Physics WG Perspectives</b>	15m
Speakers: Stephen Maple (University of Birmingham), Tyler Kutz (MIT)		
 epic_early_inclusive...		
11:30 → 11:45	<b>Semi-Inclusive Physics WG Perspectives</b>	15m
Speakers: Ralf Seidl (RIKEN), Dr Stefan Diehl (JLU Giessen and UCONN)		
 Epic_SIDIS_WG_earl...		
11:45 → 12:00	<b>Exclusive, Diffraction and Tagging WG Perspectives</b>	15m
Speakers: Raphael Dupre (JLab, CNRS, Univ. Paris-Saclay), Zhoudunming Tu (BNL)		
 Exclusive/Diffractio...		
12:00 → 12:15	<b>Jets and Heavy Flavor WG Perspectives</b>	15m
Speakers: Olga Evdokimov (JIC), Rongrong Ma (Brookhaven National Laboratory)		
 20240913_JetsHF...		
12:15 → 12:45	<b>Early Science Contributed Flash Talks</b>	
12:20	<b>Opportunities for unpolarized TMDs with early data</b>	5m
Speakers: Andrea Bressan (University of Trieste and INFN), Marco Radici (INFN - Sezione di Pavia), Salvatore Fazio (University of Calabria and INFN-Cosenza)		
 slides.pdf		
12:25	<b>Open charm production in DIS e+p and e+A collisions</b>	5m
Speakers: Dr Xuan Li (Los Alamos National Laboratory), Xuan Li (Los Alamos National Lab)		
 ePIC_early_science...		
12:30	<b>Heavy vs. medium nuclei for EIC early physics</b>	5m
Speaker: Spencer Klein (BNL)		
 KleinEICearthphysi...		
12:35	<b>Early Measurements on Saturation</b>	5m
Speaker: Thomas Ullrich (BNL)		
 discussion-ADep.pdf		
12:45 → 13:15	<b>Discussion</b>	30m

<https://indico.bnl.gov/event/24432>

# The program

**ePIC Early Science Workshop**  
Friday 13 Sept 2024, 10:30 → 13:30 US/Eastern

**Description** Connection Information: <https://www.zoomgov.com/j/16028186096?pwd=dndBRnBFSkxkN3RlThNLZlRlTjZkQk09>

Recording: <https://youtu.be/Cd0gvc1-T9k>

Early.Physics.eca.L... Early.Physics.eca.v...

**10:30 → 10:45 Introduction and Overview** 15m  
Speakers: John Lajoie (Oak Ridge National Laboratory), Silvia Dalla Torre (INFN, Trieste)  
ePIC Collaboration ...

**10:45 → 11:15 The Phase-1 Electron-Ion Collider** 30m  
Speaker: Sergei Nagaitsev  
SNagaitsev\_091324...

**11:15 → 11:30 Inclusive Physics WG Perspectives** 15m  
Speakers: Stephen Maple (University of Birmingham), Tyler Kutz (MIT)  
epic\_early\_inclusive...

**11:30 → 11:45 Semi-Inclusive Physics WG Perspectives** 15m  
Speakers: Ralf Seidl (RIKEN), Dr Stefan Diehl (JLU Giessen and UCONN)  
Epic\_SIDIS\_WG\_earl...

**11:45 → 12:00 Exclusive, Diffraction and Tagging WG Perspectives** 15m  
Speakers: Raphael Dupre (JLab, CNRS, Univ. Paris-Saclay), Zhoudunming Tu (BNL)  
Exclusive/Diffractio...

**12:00 → 12:15 Jets and Heavy Flavor WG Perspectives** 15m  
Speakers: Olga Evdokimov (JIC), Rongrong Ma (Brookhaven National Laboratory)  
20240913\_JetsHF...

**12:15 → 12:45 Early Science Contributed Flash Talks**

**12:20 Opportunities for unpolarized TMDs with early data** 5m  
Speakers: Andrea Bressan (University of Trieste and INFN), Marco Radici (INFN - Sezione di Pavia), Salvatore Fazio (University of Calabria and INFN-Cosenza)  
slides.pdf

**12:25 Open charm production in DIS e+p and e+A collisions** 5m  
Speakers: Dr Xuan Li (Los Alamos National Laboratory), Xuan Li (Los Alamos National Lab)  
ePIC\_early\_science...

**12:30 Heavy vs. medium nuclei for EIC early physics** 5m  
Speaker: Spencer Klein (BNL)  
KleinEICearthphysi...

**12:35 Early Measurements on Saturation** 5m  
Speaker: Thomas Ullrich (BNL)  
discussion-ADep.pdf

**12:45 → 13:15 Discussion** 30m

<https://indico.bnl.gov/event/24432>

Recording available !  
Elke slides

# The program

**ePIC Early Science Workshop**  
Friday 13 Sept 2024, 10:30 → 13:30 US/Eastern

**Description** Connection Information: <https://www.zoomgov.com/j/16028186096?pwd=dndBRnBFSkxkN3RlThNLZlRlTjZkQk09>

Recording: <https://youtu.be/Cd0gvc1-T9k>

Early.Physics.eca.L... Early.Physics.eca.v...

**10:30 → 10:45 Introduction and Overview** 15m  
Speakers: John Lajoie (Oak Ridge National Laboratory), Silvia Dalla Torre (INFN, Trieste)  
ePIC Collaboration ...

**10:45 → 11:15 The Phase-1 Electron-Ion Collider** 30m  
Speaker: Sergei Nagaitsev  
SNagaitsev\_091324...

**11:15 → 11:30 Inclusive Physics WG Perspectives** 15m  
Speakers: Stephen Maple (University of Birmingham), Tyler Kutz (MIT)  
epic\_early\_inclusive...

**11:30 → 11:45 Semi-Inclusive Physics WG Perspectives** 15m  
Speakers: Ralf Seidl (RIKEN), Dr Stefan Diehl (JLU Giessen and UCONN)  
Epic\_SIDIS\_WG\_earl...

**11:45 → 12:00 Exclusive, Diffraction and Tagging WG Perspectives** 15m  
Speakers: Raphael Dupre (JCLab, CNRS, Univ. Paris-Saclay), Zhoudunming Tu (BNL)  
Exclusive/Diffractio...

**12:00 → 12:15 Jets and Heavy Flavor WG Perspectives** 15m  
Speakers: Olga Evdokimov (JIC), Rongrong Ma (Brookhaven National Laboratory)  
20240913\_JetsHF...

**12:15 → 12:45 Early Science Contributed Flash Talks**

**12:20 Opportunities for unpolarized TMDs with early data** 5m  
Speakers: Andrea Bressan (University of Trieste and INFN), Marco Radici (INFN - Sezione di Pavia), Salvatore Fazio (University of Calabria and INFN-Cosenza)  
slides.pdf

**12:25 Open charm production in DIS e+p and e+A collisions** 5m  
Speakers: Dr Xuan Li (Los Alamos National Laboratory), Xuan Li (Los Alamos National Lab)  
ePIC\_early\_science...

**12:30 Heavy vs. medium nuclei for EIC early physics** 5m  
Speaker: Spencer Klein (BNL)  
KleinEICearthphysi...

**12:35 Early Measurements on Saturation** 5m  
Speaker: Thomas Ullrich (BNL)  
discussion-ADep.pdf

**12:45 → 13:15 Discussion** 30m

<https://indico.bnl.gov/event/24432>

Recording available !

Elke slides

Illuminating overview of status and prospects of accelerator by S. Nagaitsev

# The program

**ePIC Early Science Workshop**  
Friday 13 Sept 2024, 10:30 → 13:30 US/Eastern

**Description** Connection Information: <https://www.zoomgov.com/j/16028186096?pwd=dndBRnBFSkxkN3RlThNLZlRlTjZkQk09>

Recording: <https://youtu.be/Cd0gvc1-T9k>

Early.Physics.eca.L... Early.Physics.eca.v...

**10:30 → 10:45 Introduction and Overview** 15m  
Speakers: John Lajoie (Oak Ridge National Laboratory), Silvia Dalla Torre (INFN, Trieste)  
ePIC Collaboration ...

**10:45 → 11:15 The Phase-1 Electron-Ion Collider** 30m  
Speaker: Sergei Nagaitsev  
SNagaitsev\_091324...

**11:15 → 11:30 Inclusive Physics WG Perspectives** 15m  
Speakers: Stephen Maple (University of Birmingham), Tyler Kutz (MIT)  
epic\_early\_inclusive...

**11:30 → 11:45 Semi-Inclusive Physics WG Perspectives** 15m  
Speakers: Ralf Seidl (RIKEN), Dr Stefan Diehl (JLU Giessen and UCONN)  
Epic\_SIDIS\_WG\_earl...

**11:45 → 12:00 Exclusive, Diffraction and Tagging WG Perspectives** 15m  
Speakers: Raphael Dupre (JCLab, CNRS, Univ. Paris-Saclay), Zhoudunming Tu (BNL)  
Exclusive/Diffractio...

**12:00 → 12:15 Jets and Heavy Flavor WG Perspectives** 15m  
Speakers: Olga Evdokimov (JIC), Rongrong Ma (Brookhaven National Laboratory)  
20240913\_JetsHF...

**12:15 → 12:45 Early Science Contributed Flash Talks**

**12:20 Opportunities for unpolarized TMDs with early data** 5m  
Speakers: Andrea Bressan (University of Trieste and INFN), Marco Radici (INFN - Sezione di Pavia), Salvatore Fazio (University of Calabria and INFN-Cosenza)  
slides.pdf

**12:25 Open charm production in DIS e+p and e+A collisions** 5m  
Speakers: Dr Xuan Li (Los Alamos National Laboratory), Xuan Li (Los Alamos National Lab)  
ePIC\_early\_science...

**12:30 Heavy vs. medium nuclei for EIC early physics** 5m  
Speaker: Spencer Klein (BNL)  
KleinEICearthphysi...

**12:35 Early Measurements on Saturation** 5m  
Speaker: Thomas Ullrich (BNL)  
discussion-ADep.pdf

**12:45 → 13:15 Discussion** 30m

<https://indico.bnl.gov/event/24432>

Recording available !

Elke slides

Illuminating overview of status and prospects of accelerator by S. Nagaitsev

“Desiderata” of various WG’s:  
DIS, SIDIS, Excl.+Diffr.+Tagging,  
Jets+HF

# The program

**ePIC Early Science Workshop**  
Friday 13 Sept 2024, 10:30 → 13:30 US/Eastern

**Description** Connection Information: <https://www.zoomgov.com/j/16028186096?pwd=dndBRnBFSkxkN3RlThNLZlRlTjZkQk09>

Recording: <https://youtu.be/Cd0gvc1-T9k>

Early.Physics.eca.L... Early.Physics.eca.v...

**10:30 → 10:45 Introduction and Overview** 15m  
Speakers: John Lajoie (Oak Ridge National Laboratory), Silvia Dalla Torre (INFN, Trieste)  
ePIC Collaboration ...

**10:45 → 11:15 The Phase-1 Electron-Ion Collider** 30m  
Speaker: Sergei Nagaitsev  
SNagaitsev\_091324...

**11:15 → 11:30 Inclusive Physics WG Perspectives** 15m  
Speakers: Stephen Maple (University of Birmingham), Tyler Kutz (MIT)  
epic\_early\_inclusive...

**11:30 → 11:45 Semi-Inclusive Physics WG Perspectives** 15m  
Speakers: Ralf Seidl (RIKEN), Dr Stefan Diehl (JLU Giessen and UCONN)  
Epic\_SIDIS\_WG\_earl...

**11:45 → 12:00 Exclusive, Diffraction and Tagging WG Perspectives** 15m  
Speakers: Raphael Dupre (JCLab, CNRS, Univ. Paris-Saclay), Zhoudunming Tu (BNL)  
Exclusive/Diffractio...

**12:00 → 12:15 Jets and Heavy Flavor WG Perspectives** 15m  
Speakers: Olga Evdokimov (JIC), Rongrong Ma (Brookhaven National Laboratory)  
20240913\_JetsHF...

**12:15 → 12:45 Early Science Contributed Flash Talks**

**12:20 Opportunities for unpolarized TMDs with early data** 5m  
Speakers: Andrea Bressan (University of Trieste and INFN), Marco Radici (INFN - Sezione di Pavia), Salvatore Fazio (University of Calabria and INFN-Cosenza)  
slides.pdf

**12:25 Open charm production in DIS e+p and e+A collisions** 5m  
Speakers: Dr Xuan Li (Los Alamos National Laboratory), Xuan Li (Los Alamos National Lab)  
ePIC\_early\_science...

**12:30 Heavy vs. medium nuclei for EIC early physics** 5m  
Speaker: Spencer Klein (BNL)  
KleinEICearlyphysi...

**12:35 Early Measurements on Saturation** 5m  
Speaker: Thomas Ullrich (BNL)  
discussion-ADep.pdf

**12:45 → 13:15 Discussion** 30m

<https://indico.bnl.gov/event/24432>

Recording available !

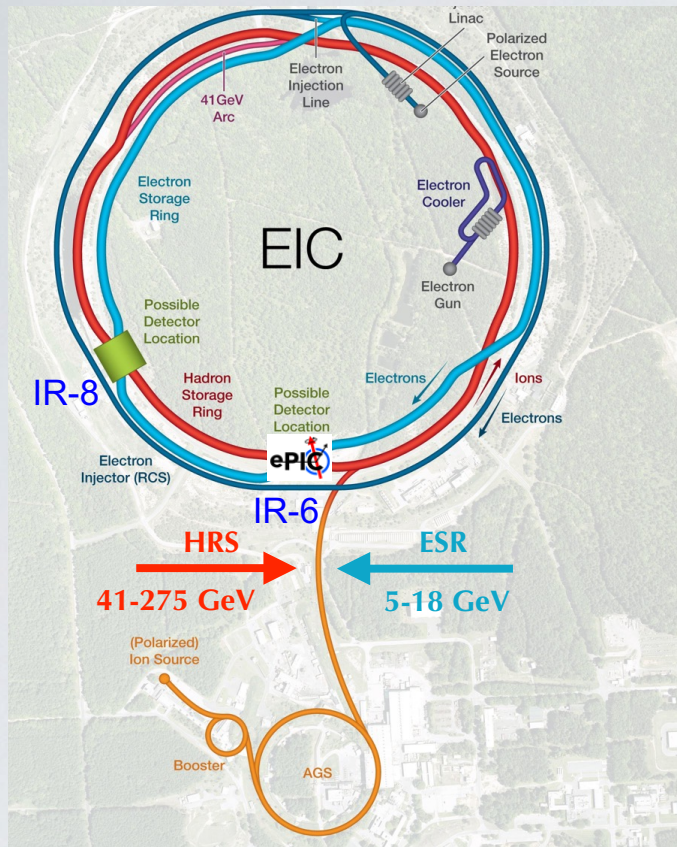
Elke slides

Illuminating overview of status and prospects of accelerator by S. Nagaitsev

“Desiderata” of various WG’s:  
DIS, SIDIS, Excl.+Diffr.+Tagging,  
Jets+HF

Flash talks on specific requests

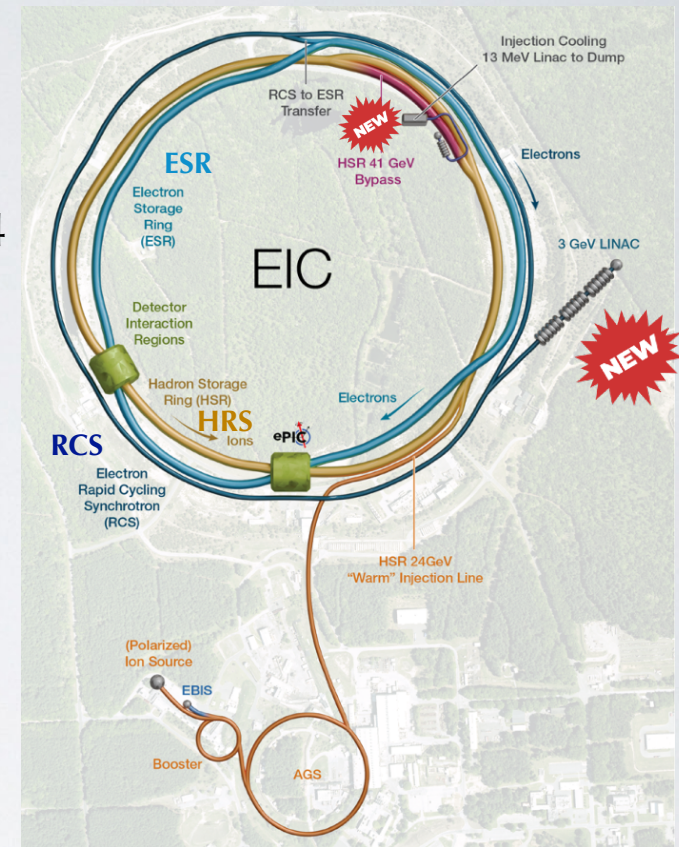
# From S.Nagaitsev slides



until  
Apr. '24



Sept. '24

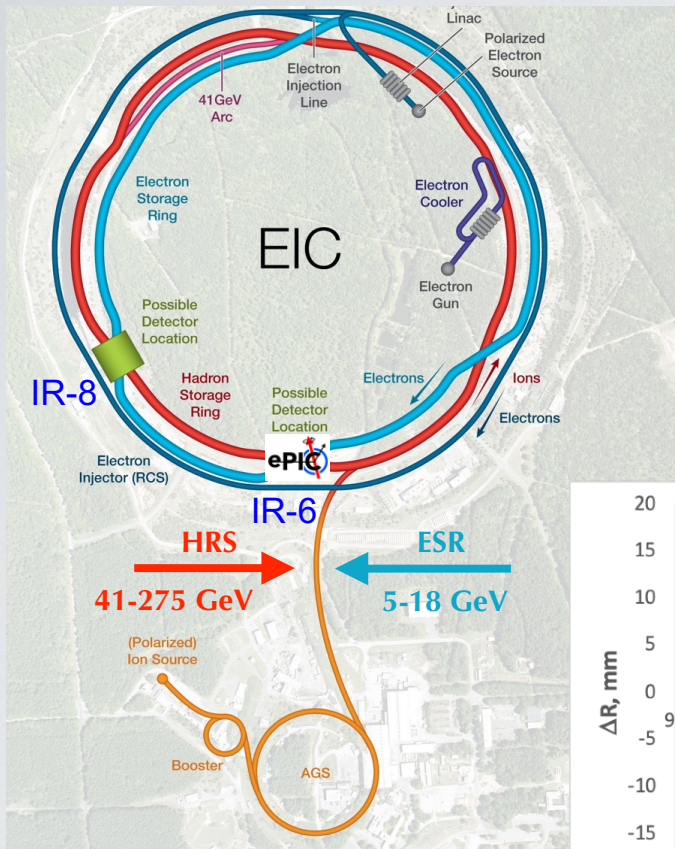


## Phase I:

- **HSR**: no 41-GeV bypass, no cooling, ~130 GeV/N, "centered hadron beam"
- **ESR**: 5-10 GeV, 7nC max, **unpolarized e-**, no crabs?
- **RCS**: at 7nC, 3 → 5-10 GeV
- beam-beam energy at **peak luminosity**



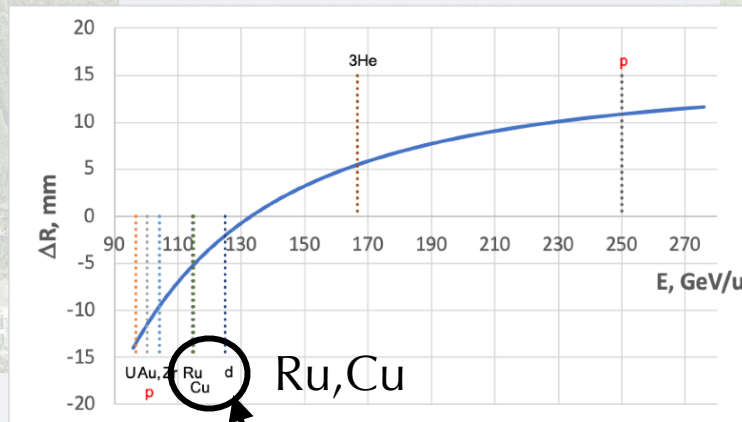
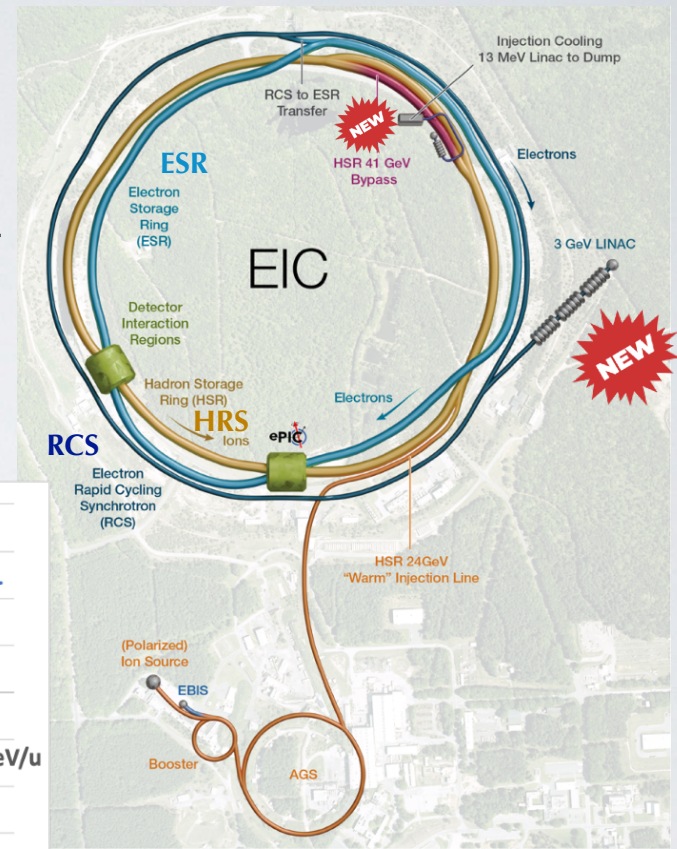
# From S.Nagaitsev slides



until  
Apr. '24



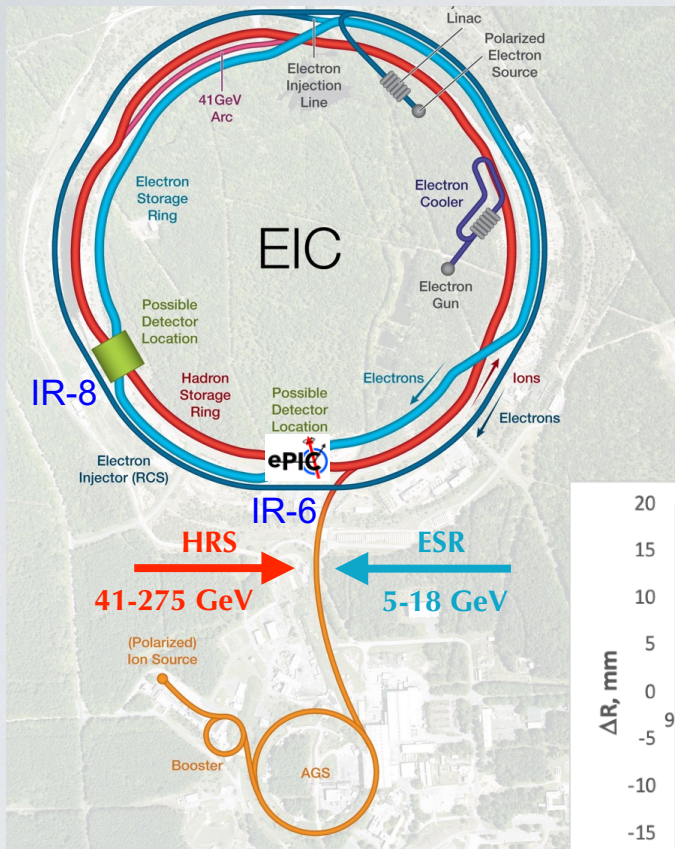
Sept. '24



## Phase I:

- **HSR**: no 41-GeV bypass, no cooling, ~130 GeV/N, "centered hadron beam"
- **ESR**: 5-10 GeV, 7nC max, **unpolarized e-**, no crabs?
- **RCS**: at 7nC, 3 → 5-10 GeV
- beam-beam energy at **peak luminosity**

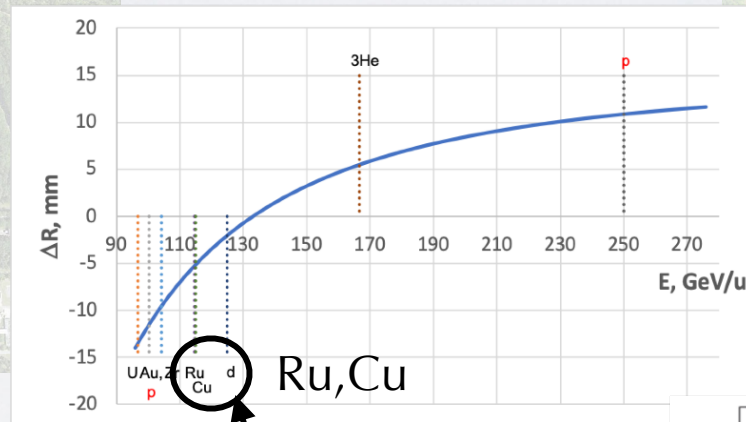
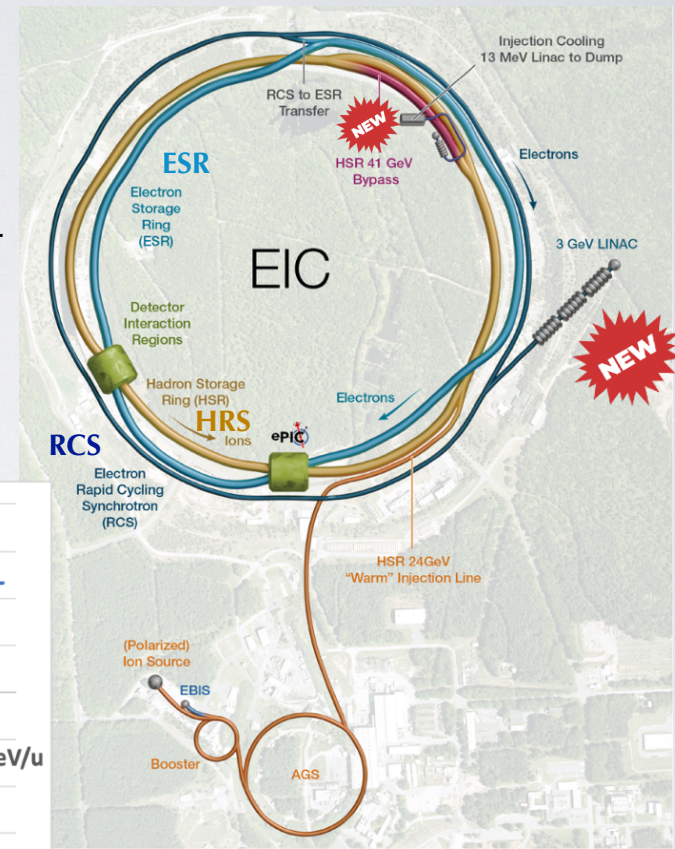
# From S.Nagaitsev slides



until  
Apr. '24



Sept. '24

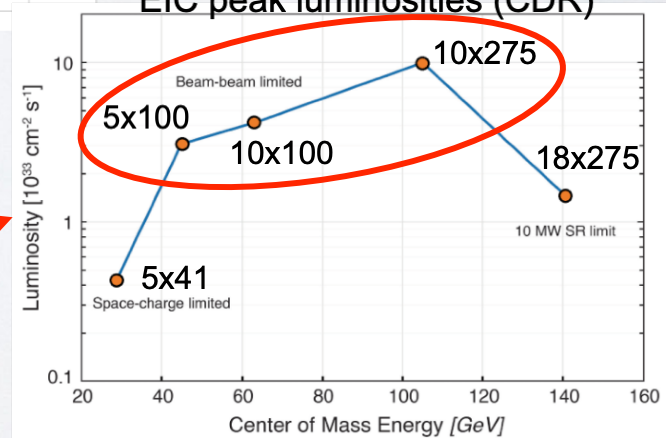


## Phase I:

- **HSR**: no 41-GeV bypass, no cooling, ~130 GeV/N, "centered hadron beam"
- **ESR**: 5-10 GeV, 7nC max, **unpolarized e-**, no crabs?
- **RCS**: at 7nC, 3 → 5-10 GeV
- beam-beam energy at **peak luminosity**

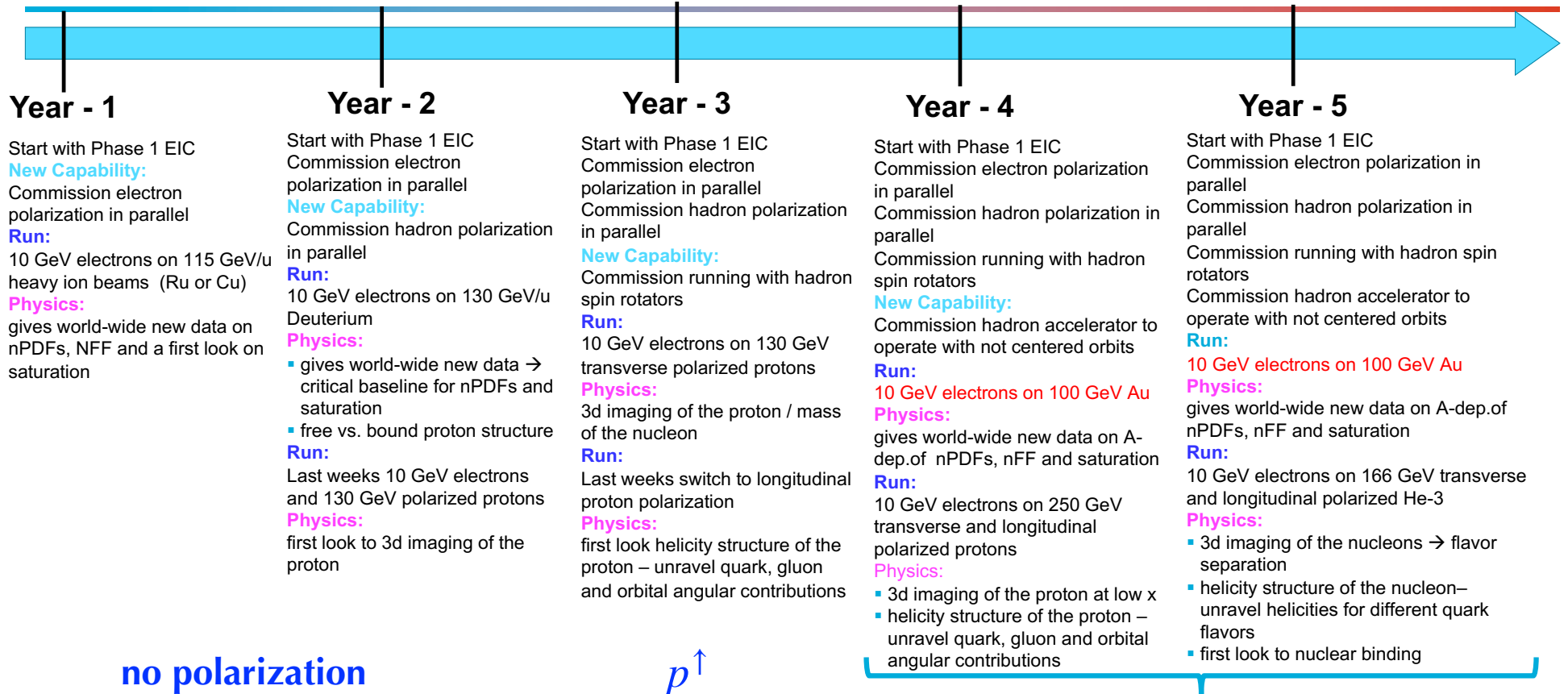
Phase I

EIC peak luminosities (CDR)



# From Elke's slides

## Proposal for EIC Science Program in the First Years



no polarization

$p^\uparrow$

Time to install additional ESR RF and HSR PS to reach design Current and max. Energies

Electron-Ion Collider

EIC Project Strategy Workshop August 21 2024

$p^\uparrow$  &  $\vec{p}$

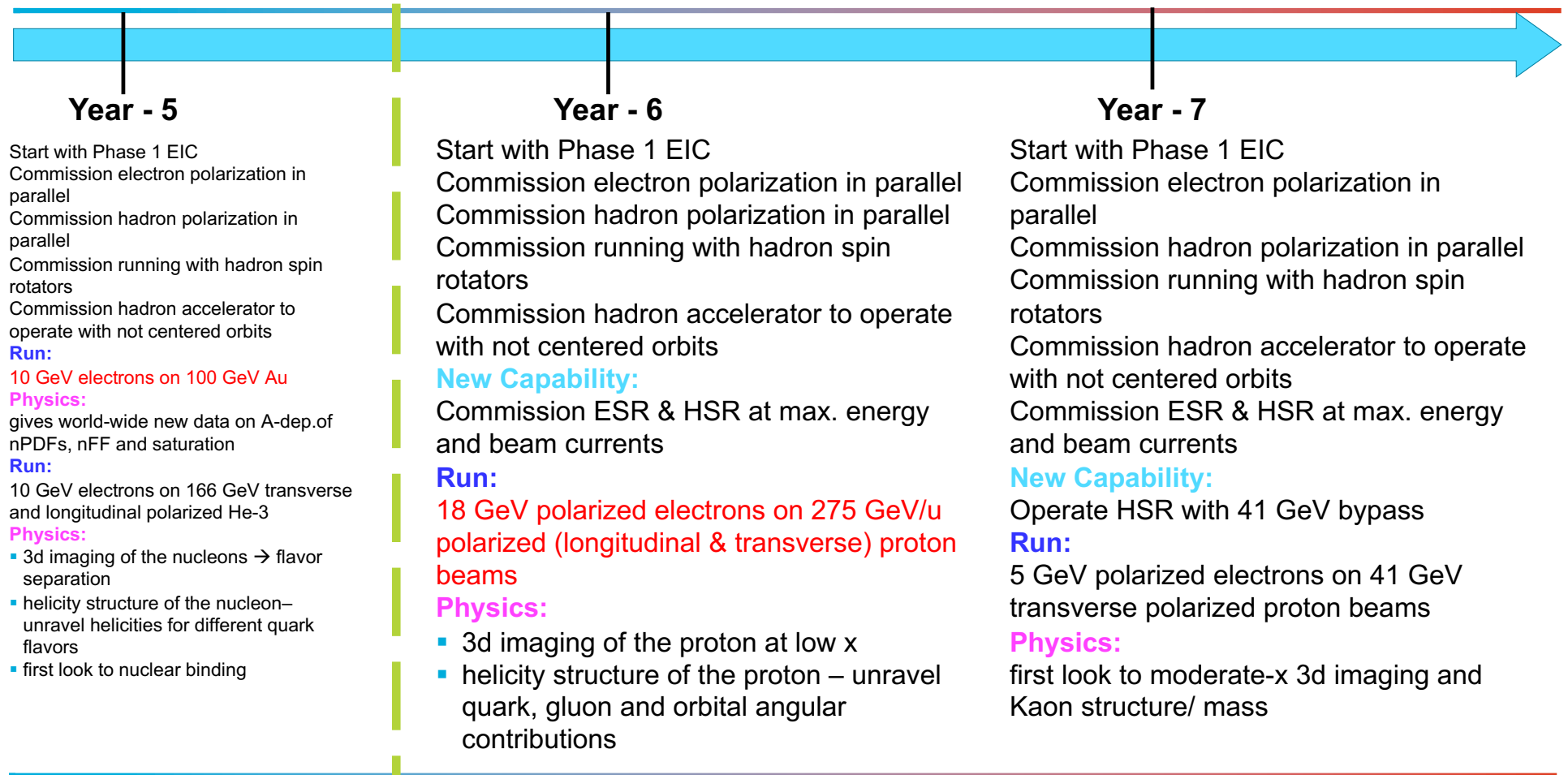
${}^3\text{He}^\uparrow$  &  $\vec{{}^3\text{He}}$

16

updates after discussion at EICUG/ePIC

# From Elke's slides

## Proposal for EIC Science Program in the First Years



Electron-Ion Collider

EIC Project Strategy Workshop August 21 2024

$\vec{e}$  &  $p^\uparrow$  &  $\vec{p}$

17

transition to polarized e- at max. energy

updates after discussion at EICUG/ePIC

- NC cross section  $\rightarrow$  PDF and nPDF

- **Ion beam**: any
- **Polarization**: not required
- **c.o.m. energy  $\sqrt{s}$** : any

- ep DIS: largest impact at high x
- eA DIS: lots of room for impact
- early eD DIS  $\rightarrow$  baseline for eA

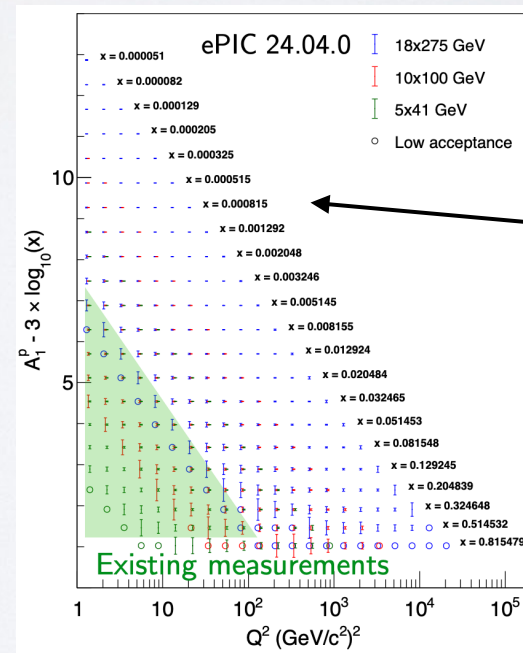
-  $F_2/F_L$  separation in p and A

- **Ion beam**: any
- **Polarization**: not required
- **c.o.m. energy  $\sqrt{s}$** : multiple

- better larger  $\Delta(\sqrt{s}) \rightarrow$  larger lever arm
- better  $2\sqrt{s}$  on same target early on

- N spin structure function

- **Ion beam**: p and  $^3\text{He}$
- **Polarization**: both electron and hadron
- **c.o.m. energy  $\sqrt{s}$** : any
- $\delta A/A \sim 1/(P_e P_h \sqrt{N}) \rightarrow$  high polarization
- neutron  $\rightarrow$   $^3\text{He}$  beam



largest impact at lowest x  $\rightarrow$  highest  $\sqrt{s}$

start with 10 x 100 ?

- **Year 1:** 10x115 with heavy ion beams (Ru, Cu)
  - nPDF and nFF, poorly known in EIC kin.
- **Year 2:** 10x130 with Deuterium
  - proton & neutron PDF, FF; improve strange and down PDF?
  - early unpolarized TMD; first look at TMD evolution?
- **Year 3:** 10x130 with  $p^\uparrow$  ; last weeks with also  $\vec{p}$ 
  - structure functions with target polarization; early look at  $A_{UT}$   
(  $A_{LL}$  still not possible )

limited luminosity → no fully differential measurements

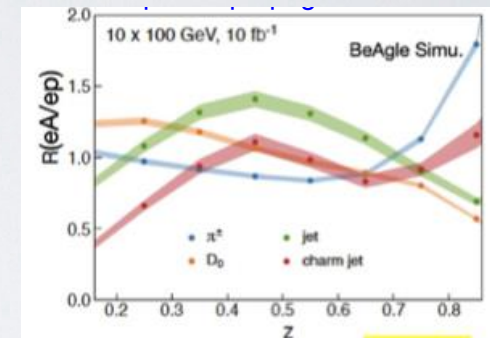
# Exclusive WG

Raphaël Dupré (Paris-Saclay)  
Rachel Montgomery (Glasgow)  
Kong Tu (BNL)

- **Year 1-2:** low luminosity, no polarization, medium-light ions
    - $[\sigma_{\text{diffr}}/\sigma_{\text{tot}}(\text{Zr, Cu})] / [\sigma_{\text{diffr}}/\sigma_{\text{tot}}(\text{p})]$ : hints of saturation
    - vector meson production: gluon spatial distribution (need special FF detectors)
    - DIS on deuteron with tagging: neutron structure, SRC.. (need OMD and ZDC)
  - **Year 3-4:** some polarization, increased luminosity, proton target
    - DVCS: proton 3D-structure (need Roman Pots, high lumi)
    - (di)jets and  $\Upsilon$  production: OAM and origin of mass (need all detectors, high lumi)
    - backward u-channel production, DEMP:  $\pi / K$  structure functions (high lumi, need all detectors)
  - **Year 5-7:** Heavy ions and protons
    - (in)coherent physics with  $^3\text{He}$ : DVCS, VM, ... (need FF detectors, high lumi)
    - eA (A=Au, Pb) at highest  $\sqrt{s}$ : gluon saturation ( " " " " " )
    - near-threshold  $J/\psi$  and  $\Upsilon$  production in ep at lower  $\sqrt{s}$ : origin of mass (need Roman Pots, high lumi)
- need FF detectors, high lumi and polarized e- as early as possible

- **Running conditions:** ep & eA (A=Au preferred) at 10x100

→ measuring  $D^0, \bar{D}^0, \Lambda_c, \dots$  : charm structure function  $F_2^{c\bar{c}}$  at large x  
constrain gluon nPDF at large x  
fragmentation & hadronization (ep  $\neq$  eA ?)  
parton propagation in nucleus



→ measuring jets: TMD measurements complimentary to SIDIS  
(year  $\geq 3$  , polarized TMDs in proton: Sivers and Collins effects)

(high  $\sqrt{s}$  preferred)



# Flash Talks

## Opportunities for unpolarized TMDs with early data

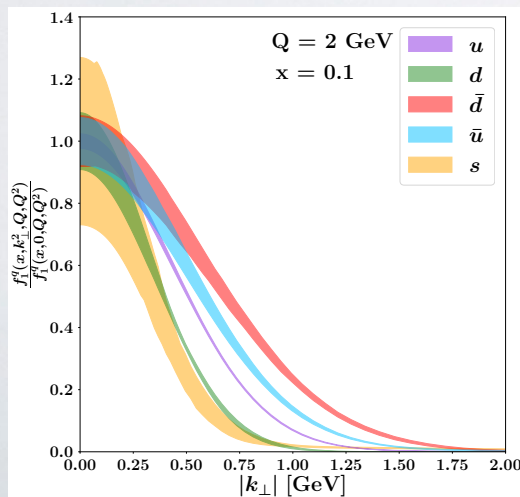
Marco Radici, INFN - Pavia  
 Andrea Bressan, INFN & Univ. - Trieste  
 Salvatore Fazio, INFN & Univ. Calabria

- SIDIS with unpolarized electron and proton
- conditions for TMD factorization:  $M^2 \ll Q^2$   
 $q_T^2 = P_{hT}^2/z^2 \ll Q^2 \rightarrow$  neglect higher twists
- integrate azimuthal angle of final hadron,  $\int d\phi_h$

$$\frac{d\sigma}{dx dz dq_T dQ} = \frac{8\pi^2 \alpha^2 z^2}{2xQ^3} Y_+ [F_{UU,T}(x, z, q_T^2, Q^2)] \quad Y_+ = [1 + (1 - Q^2/xs)^2]$$

$$F_{UU,T} = x \mathcal{H}(Q^2) \sum_q e_q^2 \left[ f_1^q \otimes D_1^{q \rightarrow h} \right]$$

hard part      TMDPDF      TMDFF



TMDPDF  
 (normalized at  $k_T=0$ )

**first time  
 flavor dependence  
 of quark intrinsic  $k_T$**

### MAPTMD24 extraction

*Bacchetta et al. (MAP Coll.),  
 JHEP 08 (24) 232, arXiv:2405.13833*

$N_{\text{dat}} = 2031$  (484 DY + 1547 SIDIS)  
 $\chi^2/N_{\text{dat}} = 1.08$ , N<sup>3</sup>LL accuracy

# The EIC impact: quark up

$x = 0.1$

$x = 0.001$

$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

(conditions of simulation campaign in May)

**MAPTMD24** 2031

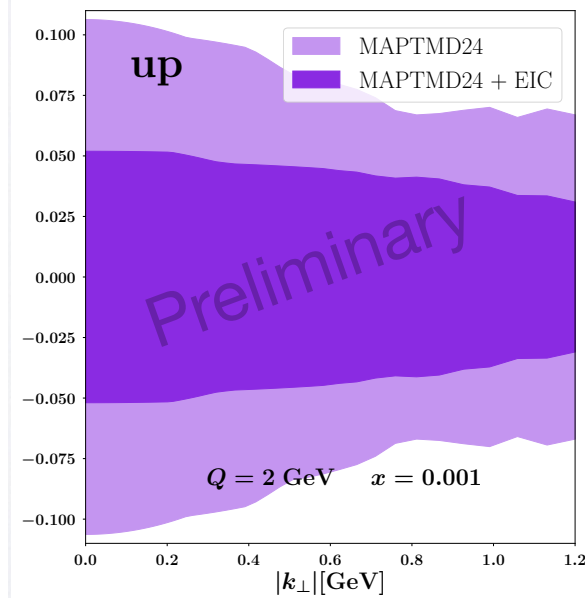
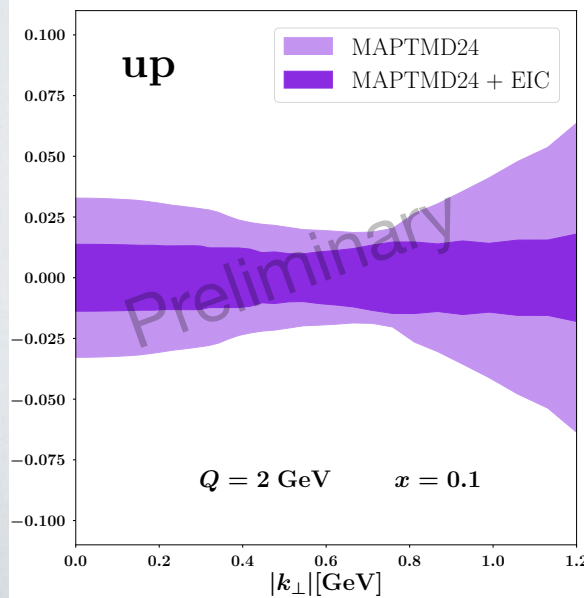
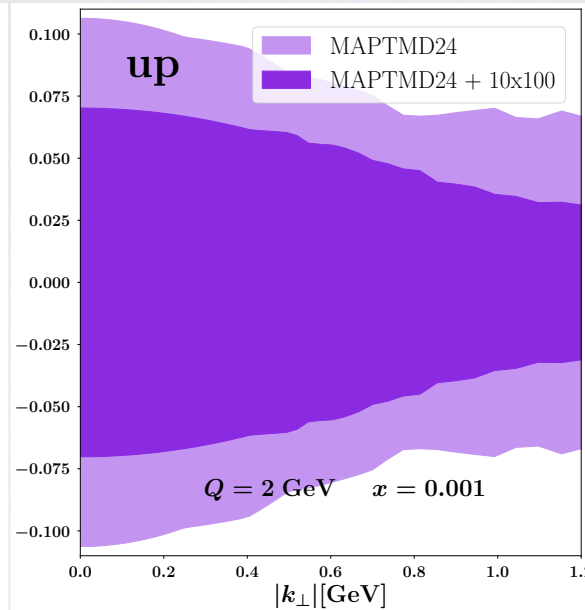
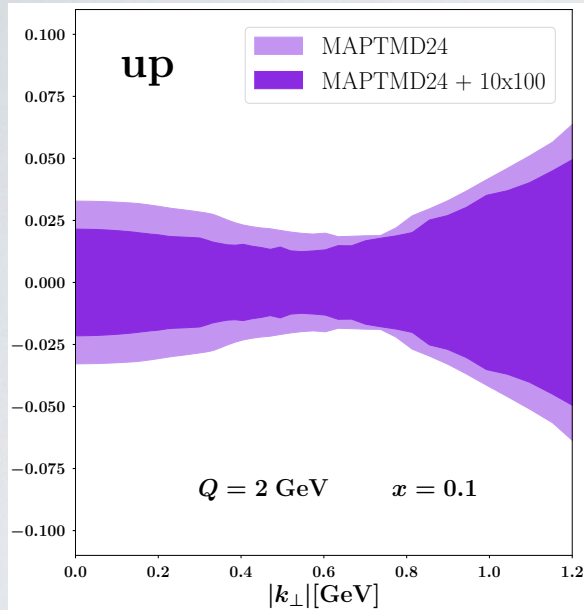
EIC	# pts.	lumi [fb <sup>-1</sup> ]
10x100	1611	51.3

significant impact (at large x)  
summing on all energies

**MAPTMD24** 2031

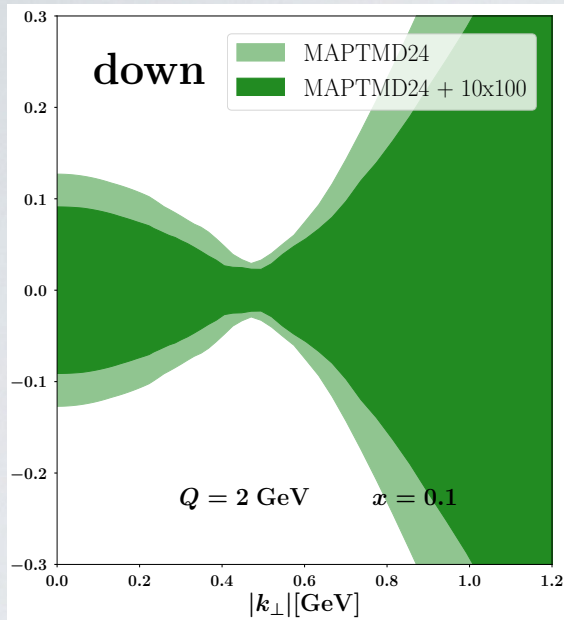
EIC	# pts.	lumi [fb <sup>-1</sup> ]
5x41	1273	2.85
10x100	1611	51.3
18x275	1648	10

L. Rossi, Ph.D. Thesis, in preparation

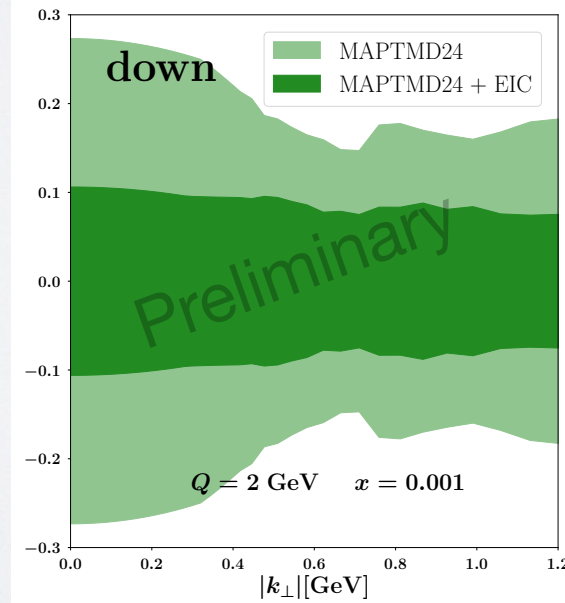
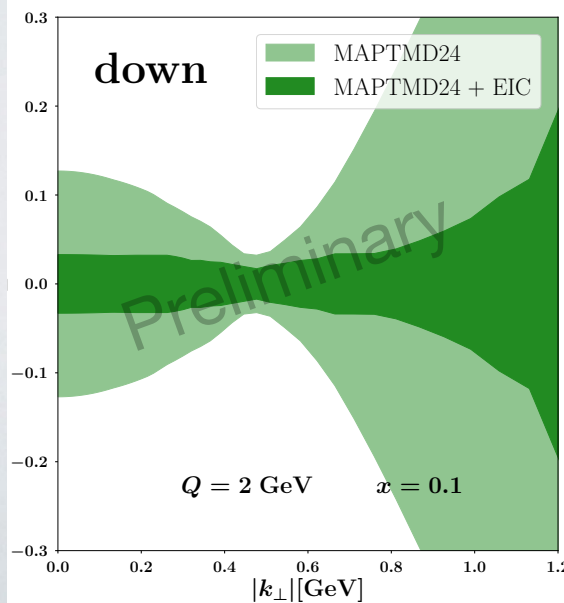
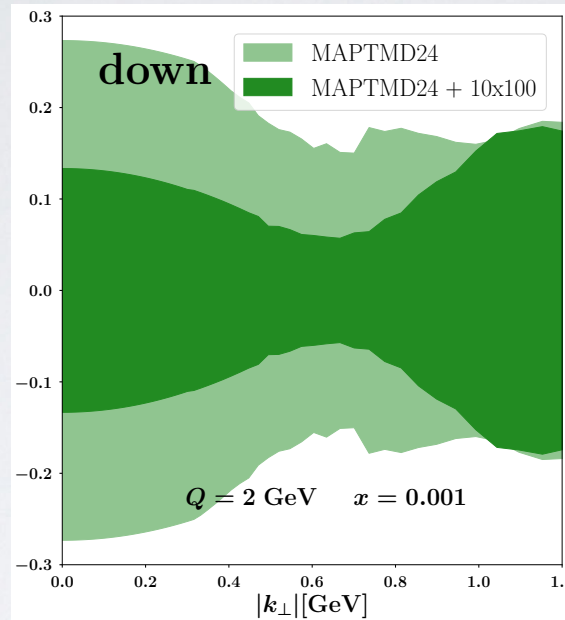


# The EIC impact: quark down

$x = 0.1$



$x = 0.001$



$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

(conditions of simulation campaign in May)

**MAPTMD24** 2031

EIC	# pts.	lumi [fb <sup>-1</sup> ]
10x100	1611	51.3

significant impact (at large x)  
 summing on all energies  
 significant impact at small x  
 already with 10x100

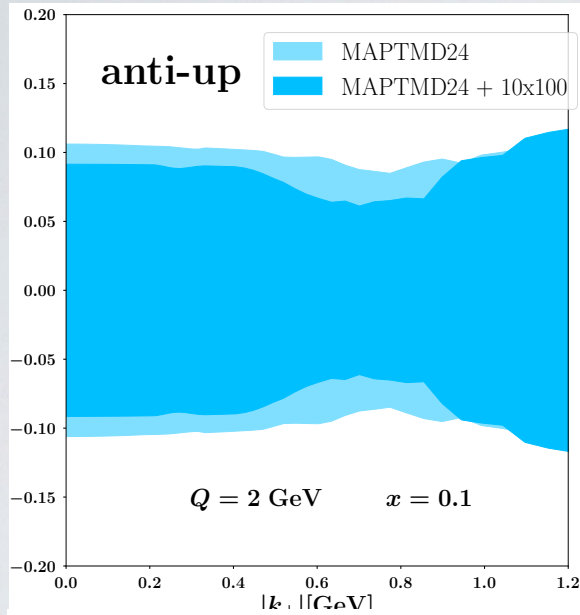
**MAPTMD24** 2031

EIC	# pts.	lumi [fb <sup>-1</sup> ]
5x41	1273	2.85
10x100	1611	51.3
18x275	1648	10

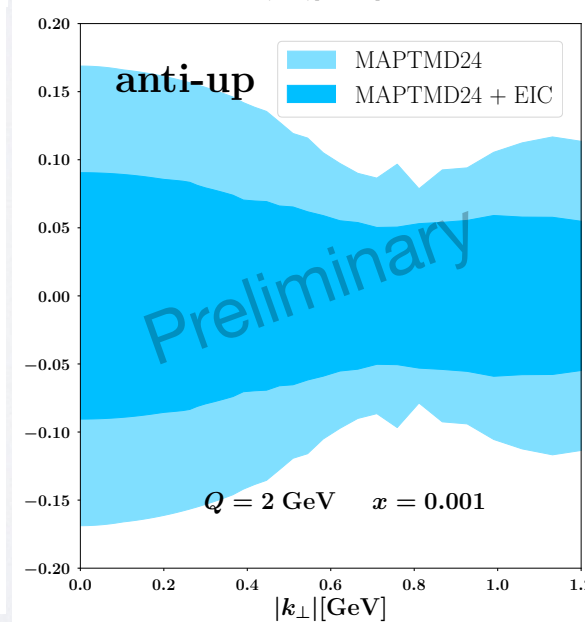
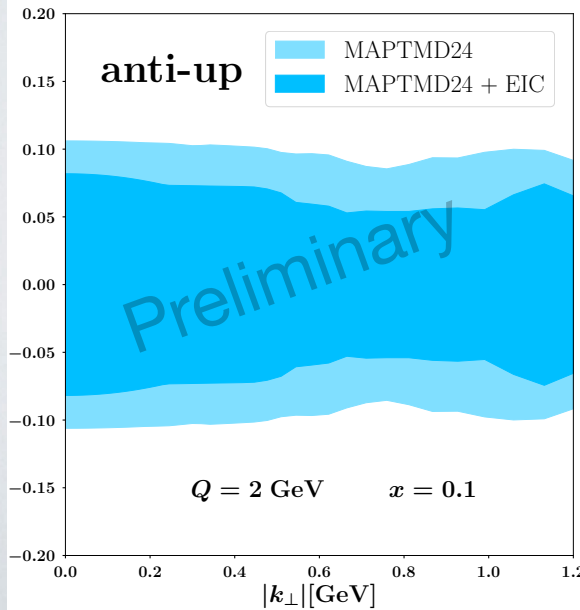
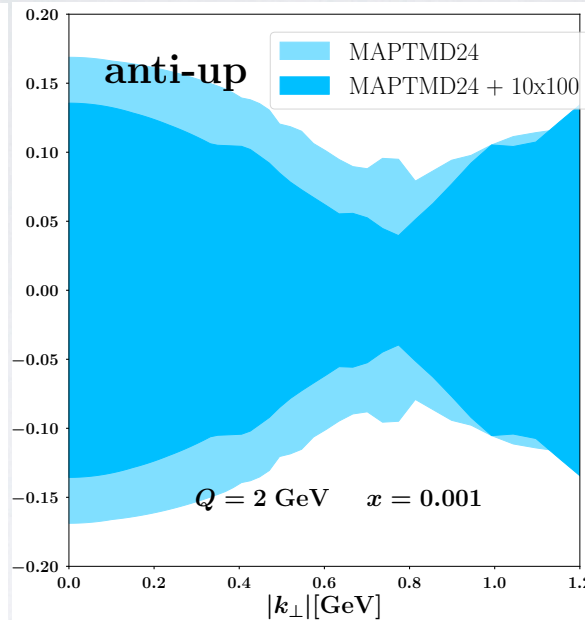
L. Rossi, Ph.D. Thesis, in preparation

# The EIC impact: quark anti-up

$x = 0.1$



$x = 0.001$



$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

(conditions of simulation campaign in May)

MAPTMD24 2031

EIC	# pts.	lumi [fb <sup>-1</sup> ]
10x100	1611	51.3

significant impact at small  $x$   
summing on all energies

MAPTMD24 2031

EIC	# pts.	lumi [fb <sup>-1</sup> ]
5x41	1273	2.85
10x100	1611	51.3
18x275	1648	10

L. Rossi, Ph.D. Thesis, in preparation

# The EIC impact: quark anti-down

$x = 0.1$

$x = 0.001$

$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

(conditions of simulation campaign in May)

**MAPTMD24** 2031

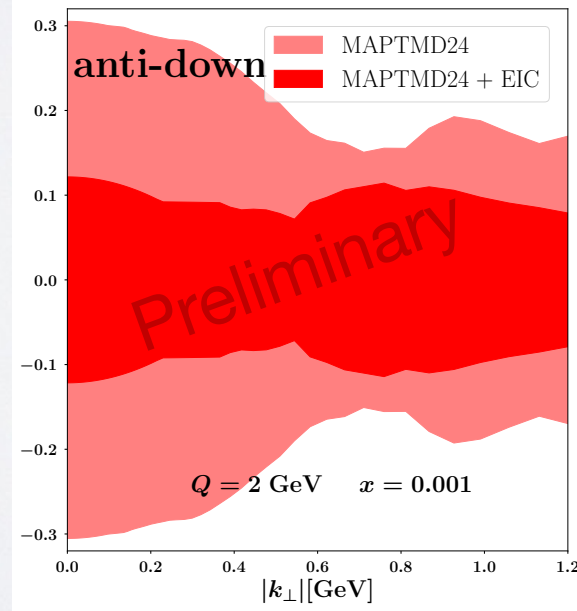
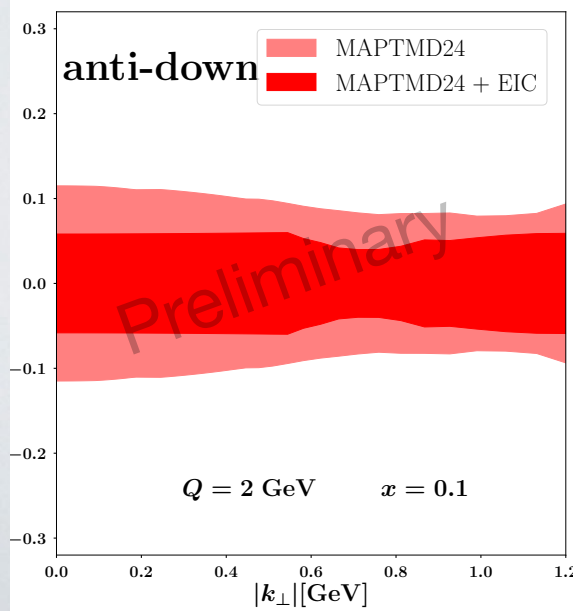
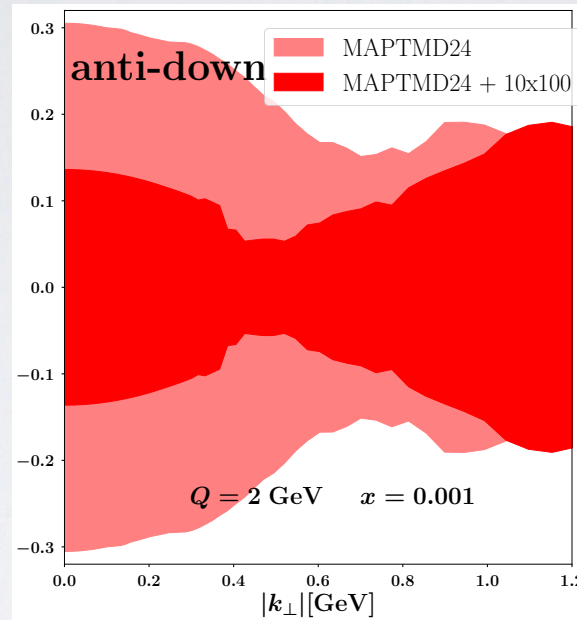
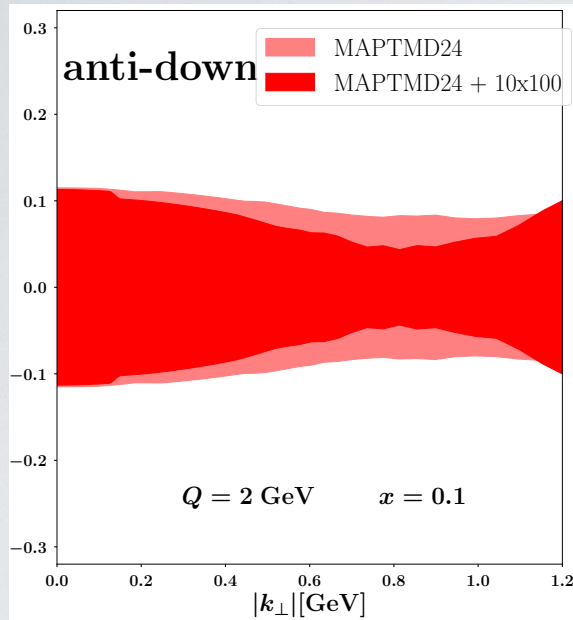
EIC	# pts.	lumi [fb <sup>-1</sup> ]
10x100	1611	51.3

significant impact at small  $x$   
summing on all energies  
but already at 10x100

**MAPTMD24** 2031

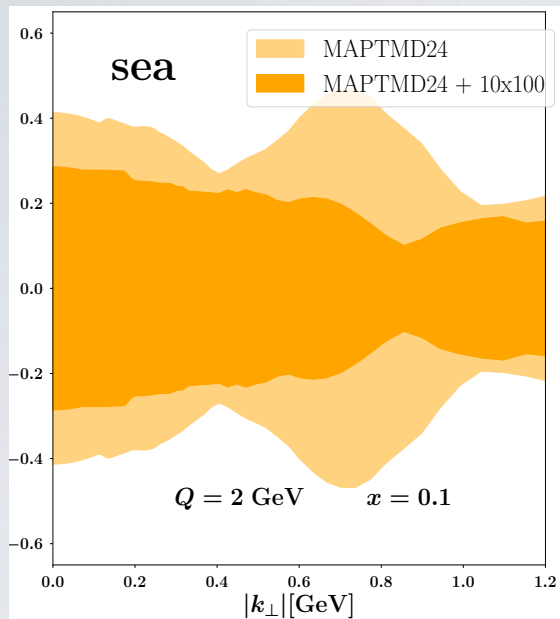
EIC	# pts.	lumi [fb <sup>-1</sup> ]
5x41	1273	2.85
10x100	1611	51.3
18x275	1648	10

L. Rossi, Ph.D. Thesis, in preparation

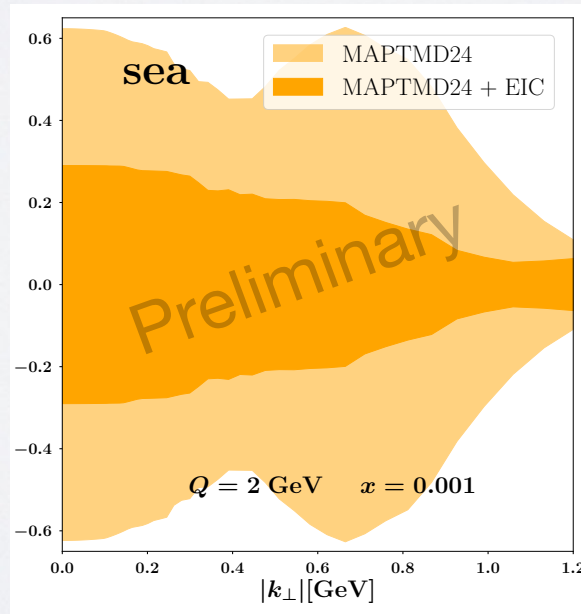
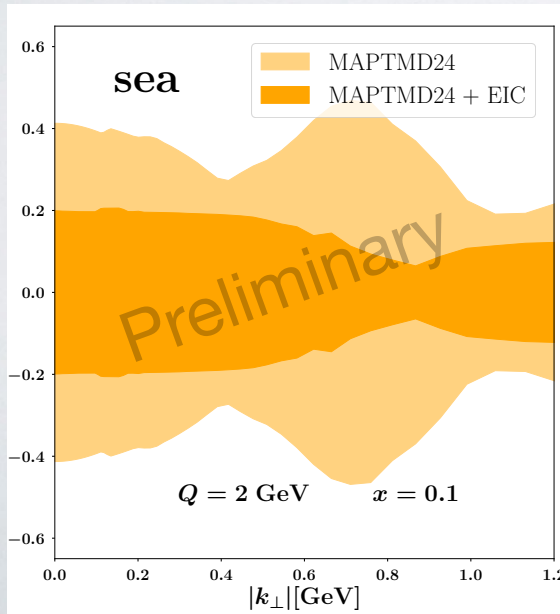
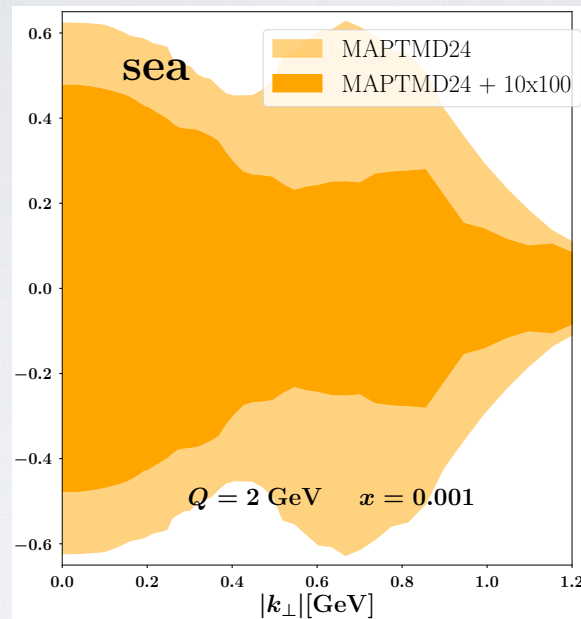


# The EIC impact: sea quarks

$x = 0.1$



$x = 0.001$



$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

(conditions of simulation campaign in May)

<b>MAPTMD24</b>	2031	
<b>EIC</b>	<b># pts.</b>	<b>lumi [fb<sup>-1</sup>]</b>
10x100	1611	51.3

significant impact summing  
on all energies  
particularly at small x

<b>MAPTMD24</b>	2031	
<b>EIC</b>	<b># pts.</b>	<b>lumi [fb<sup>-1</sup>]</b>
5x41	1273	2.85
10x100	1611	51.3
18x275	1648	10

L. Rossi, Ph.D. Thesis, in preparation

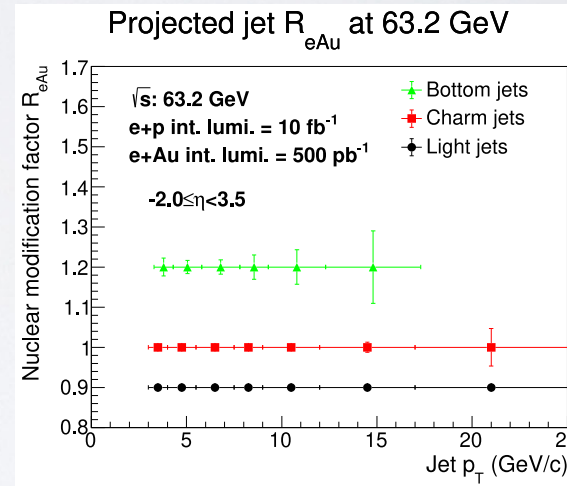
# Flash Talks

## Open charm production in DIS e+p and e+A collisions

Xuan Li, LANL

Heavy flavor production at 10x100 → constrain PDF & nPDF  
hadronization in medium

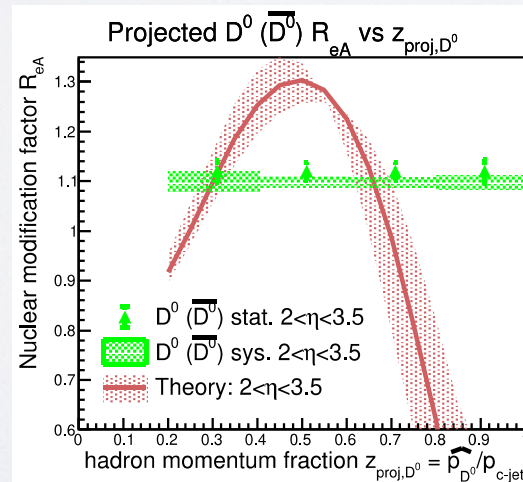
Example #1: projected jet  $R_{eA} = \frac{1}{A} \frac{\sigma_{eA}}{\sigma_{ep}}$



parton  
energy loss

Example #2:  $R_{eA}$  of  $D^0$   
inside charm jet

discriminating models  
of heavy flavor  
production in medium



# Flash Talks

## Heavy vs. medium nuclei for EIC early physics

Spencer Klein, LBNL

eA at  $10 \times 110$  GeV/N with Ruthenium (Ru) and Copper (Cu)

Ru  $\sim 23\%$  smaller than Pb; Cu  $\sim 33\%$  smaller than Pb

- smaller shadowing      need more data to measure difference from no-shadowing
- smaller path length for energy loss      coherent energy loss  $\sim (\text{length})^2$   
→ photoproduction of  $J/\psi$  at large  $p_T$
- extensive RHIC / LHC data for comparison purposes



# Flash Talks

## Early measurements on saturation

Thomas Ullrich, BNL

Key measurement:  $A$  &  $Q^2$  dependence of

$$R = \frac{\sigma_{\text{diff}}/\sigma_{\text{tot}}(eA)}{\sigma_{\text{diff}}/\sigma_{\text{tot}}(ep)}$$

$$Q^2 < Q_S^2$$

$$Q^2 > Q_S^2$$

saturation

$$R \sim Q^2$$

$$R \sim 1/Q^6$$

$$R(t=0) \sim A^{4/3} - A^{5/3}$$

$$R(t=0) \sim A^2$$

$$R \sim A^{2/3} - A$$

$$R \sim A^{4/3}$$

no saturation

different trend

large  $A$  more favorable; need anyway to vary  $A$   
need measurement on  $p$  as a reference

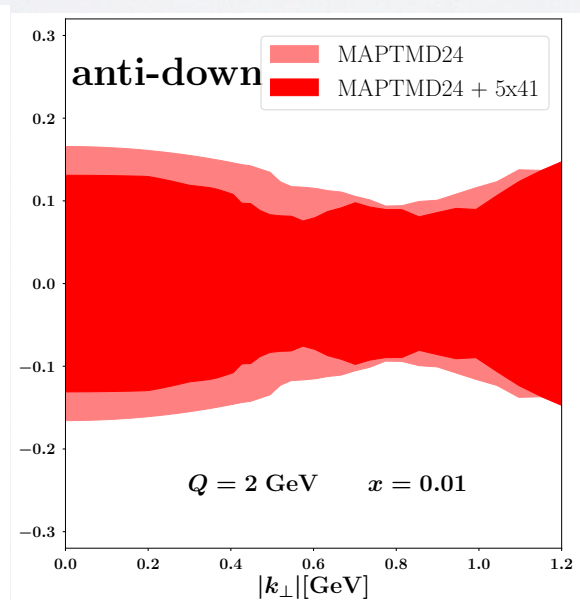
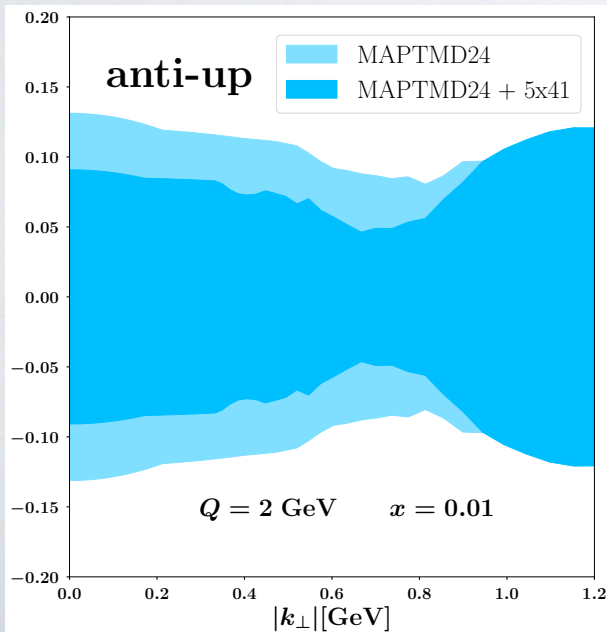
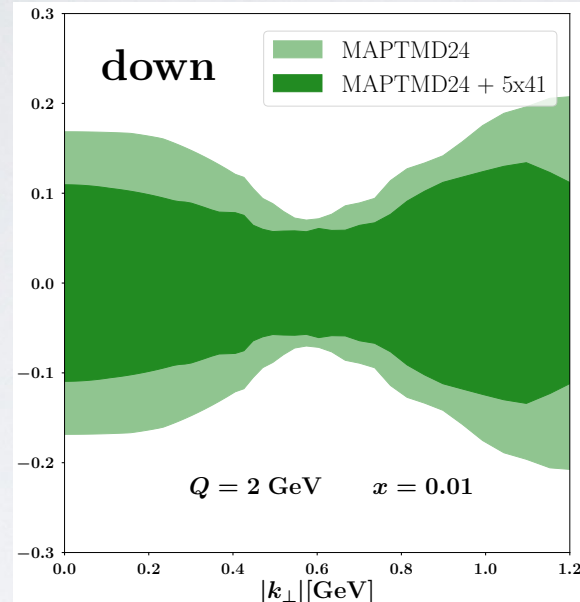
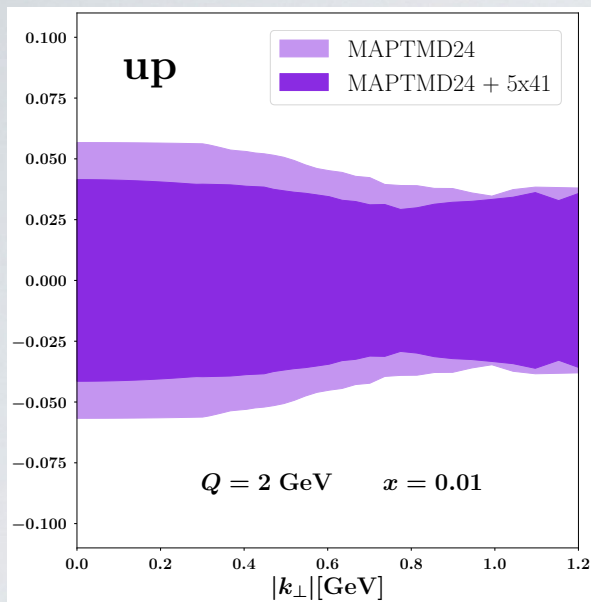
# Future plans

- Future discussions planned at the 2025 ePIC collaboration meeting, and probably in another ad-hoc meeting in March 2025
- Meantime, discussions within groups are encouraged and/or concerns with Phase-I choices are welcome (but “~70% of Phase-I is constrained by accelerator commissioning” - A. Deshpande)
- Early Science planning and TDR efforts should run in parallel because
- **Phase-I Physics:** start of promised NSAC/NAS science program  
alignment with order in commissioning the collider  
having new physics results early to get impact papers
- **TDR:** demonstrate that the ePIC detector is able to address the full EIC science program as defined in the NAS report



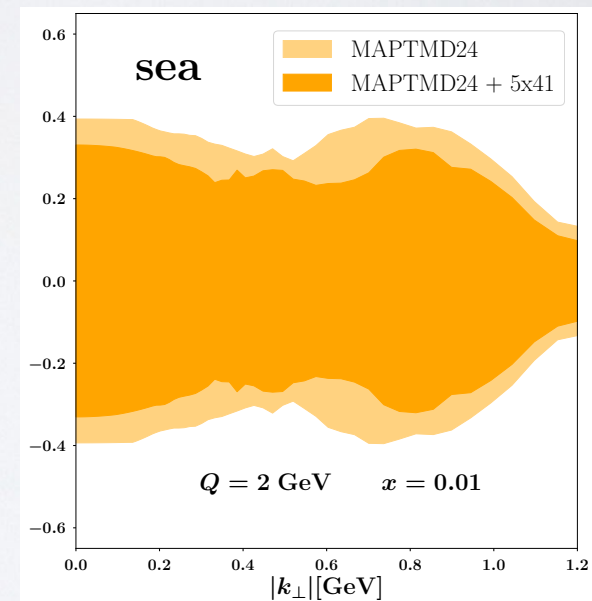
# Backup slides

# The EIC impact: 5x41, $x = 0.1$



$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

	MAPTMD24	2031	# pts.	lumi [fb <sup>-1</sup> ]
<b>EIC</b>	5x41	1273	2.85	

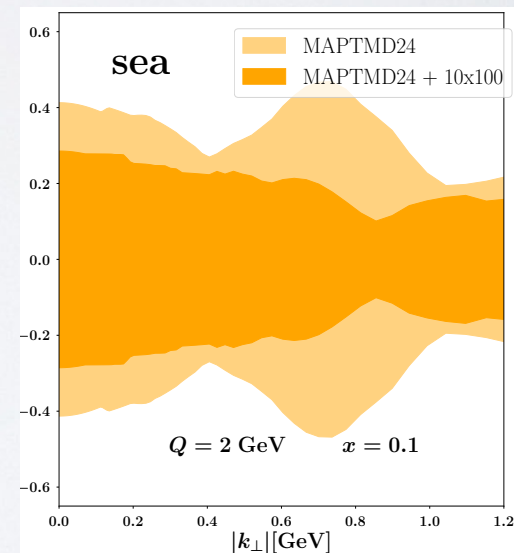
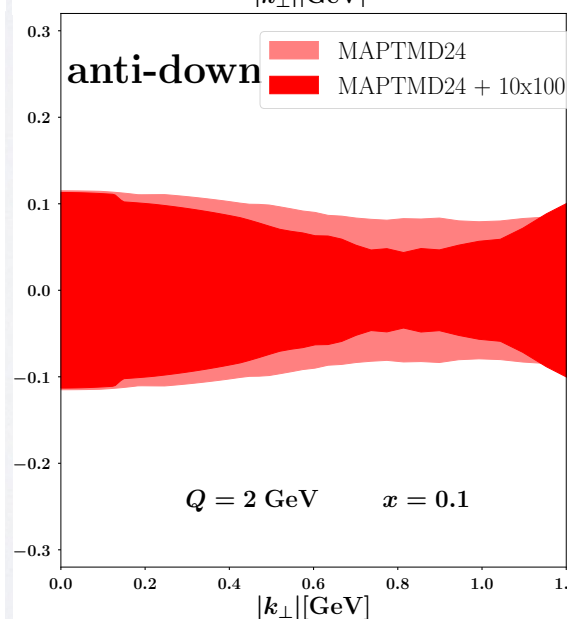
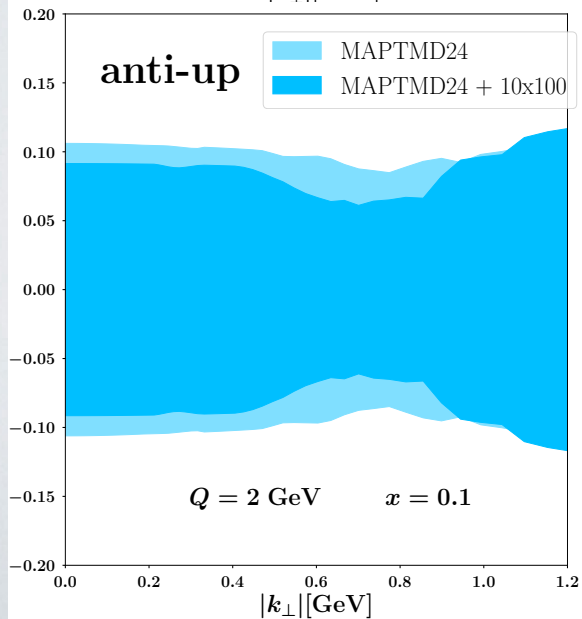
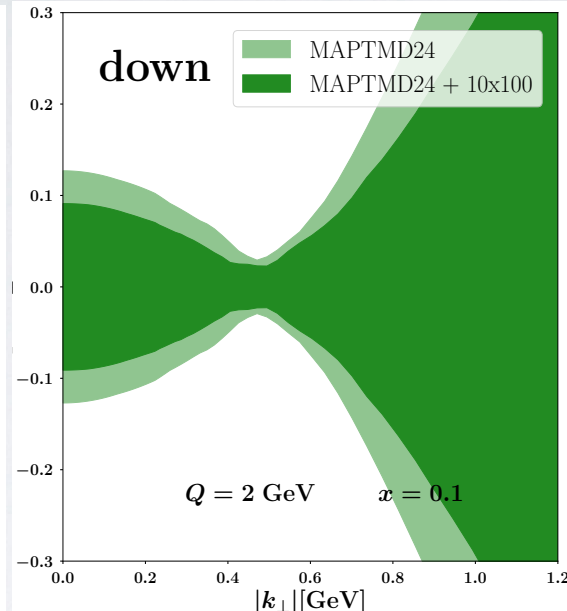
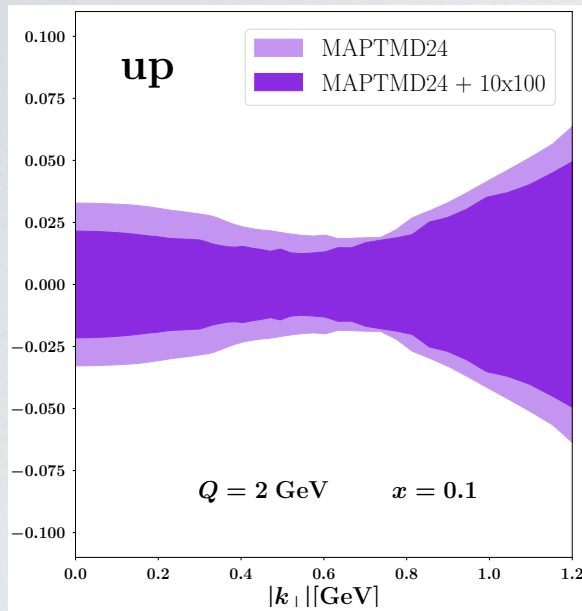


# The EIC impact: 10x100, $x = 0.1$

$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

<b>MAPTMD24</b>	2031	
<b>EIC</b>	<b># pts.</b>	<b>lumi [fb<sup>-1</sup>]</b>
10x100	1611	51.3

(conditions of simulation campaign in May)



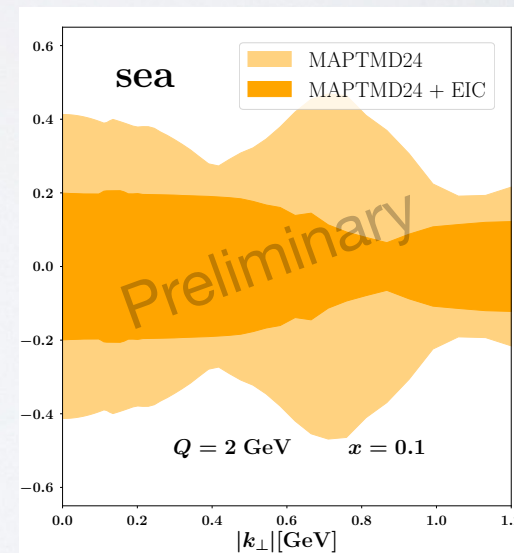
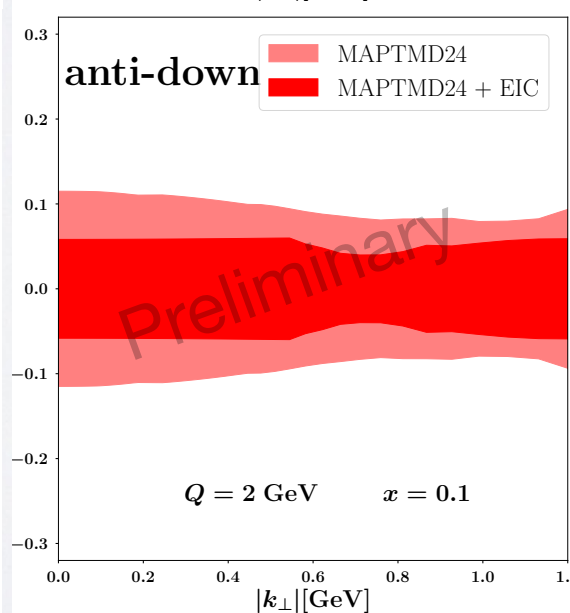
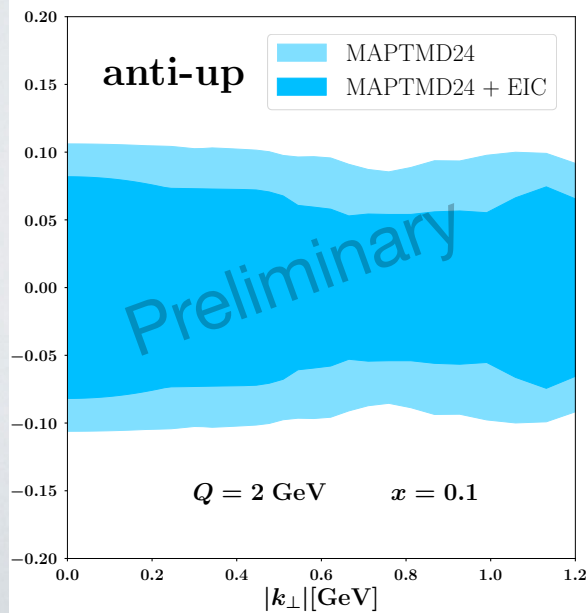
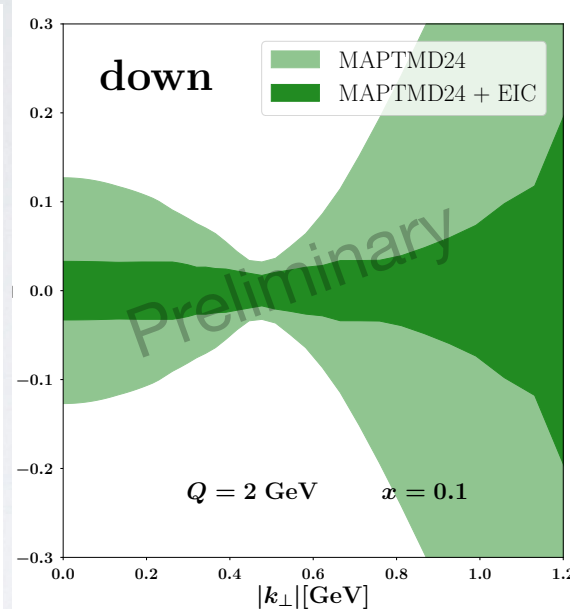
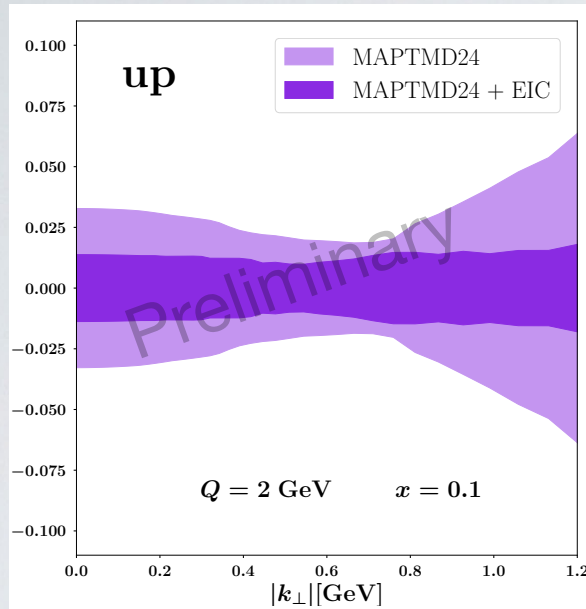
L. Rossi, Ph.D. Thesis, in preparation

# The EIC impact: all energies, $x = 0.1$

$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

	MAPTMD24	2031	EIC	# pts.	lumi [fb <sup>-1</sup> ]
			5x41	1273	2.85
			10x100	1611	51.3
			18x275	1648	10

(conditions of simulation campaign in May)



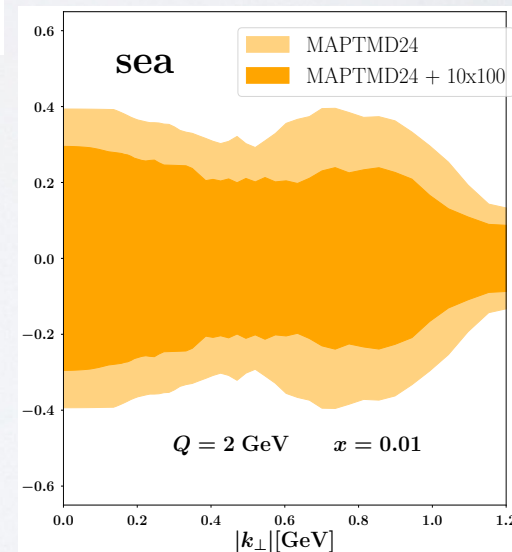
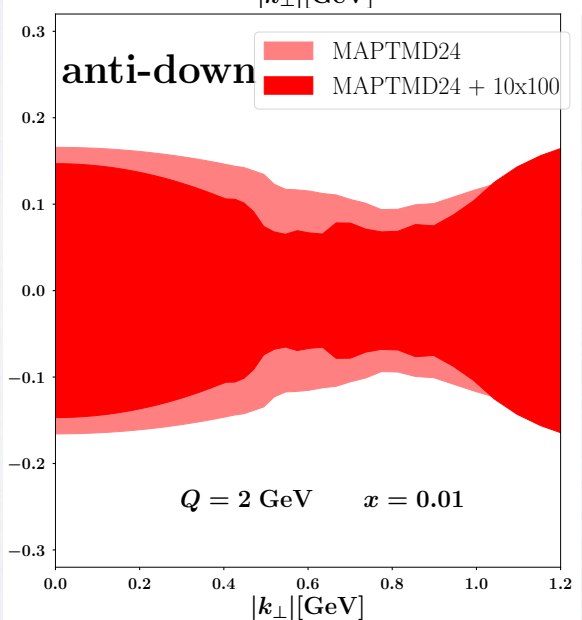
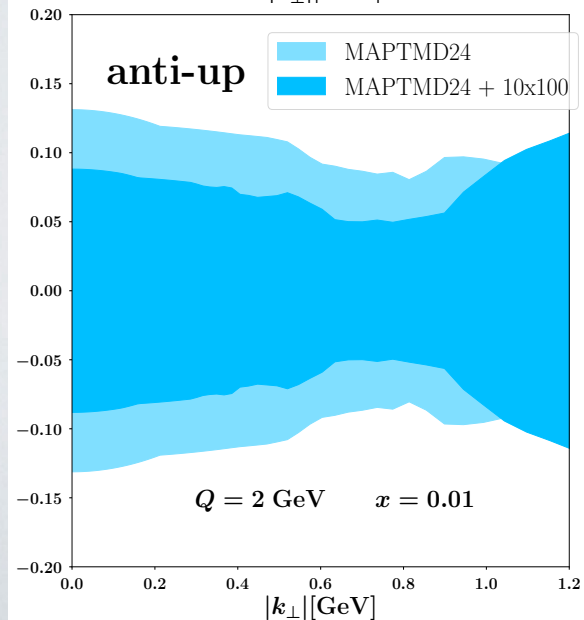
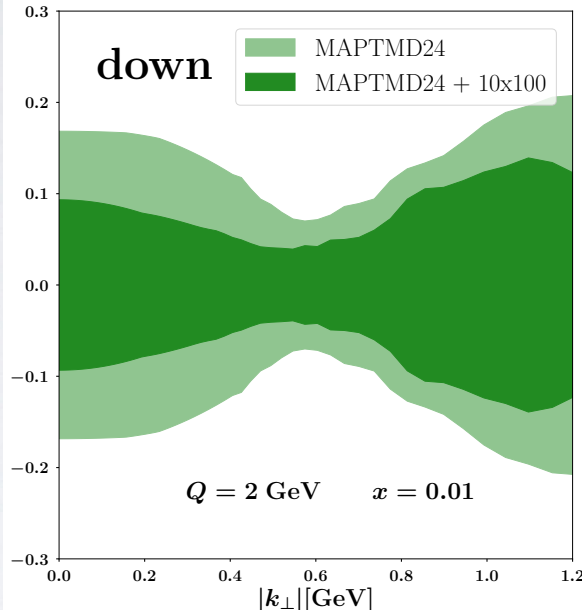
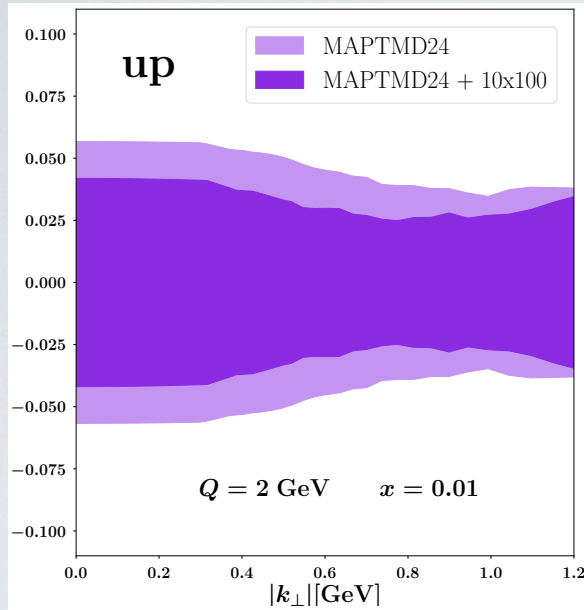
L. Rossi, Ph.D. Thesis, in preparation

# The EIC impact: 10x100, $x = 0.01$

$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

<b>MAPTMD24</b>	2031	
<b>EIC</b>	<b># pts.</b>	<b>lumi [fb<sup>-1</sup>]</b>
10x100	1611	51.3

(conditions of simulation campaign in May)



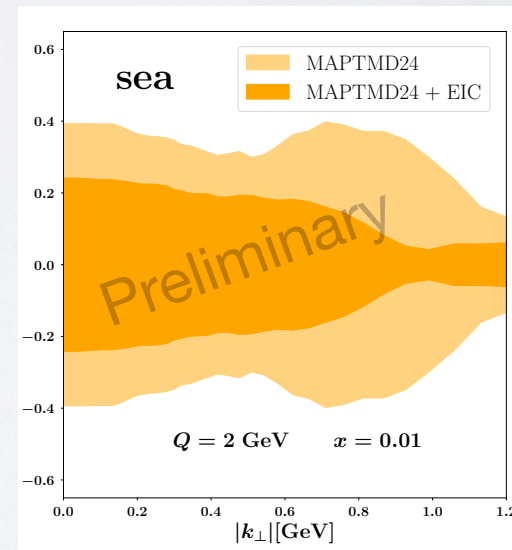
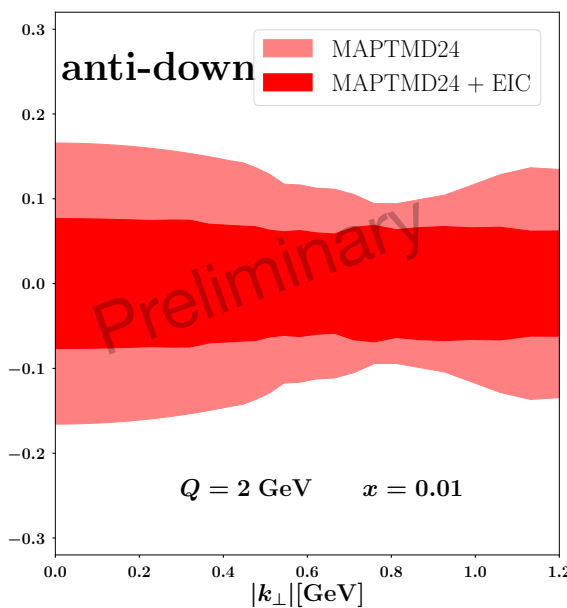
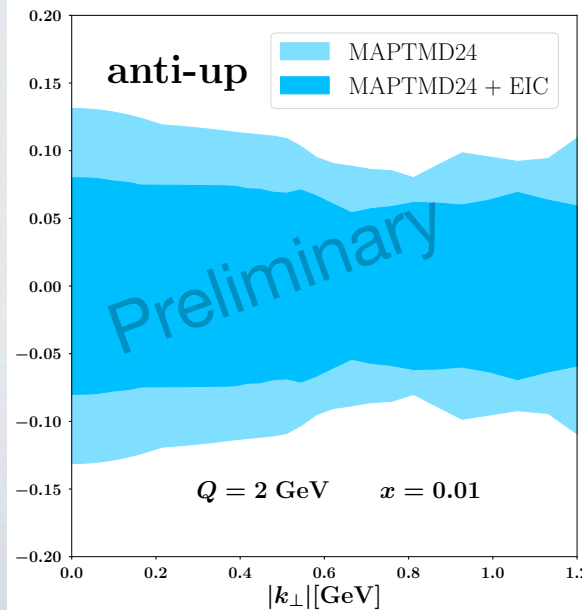
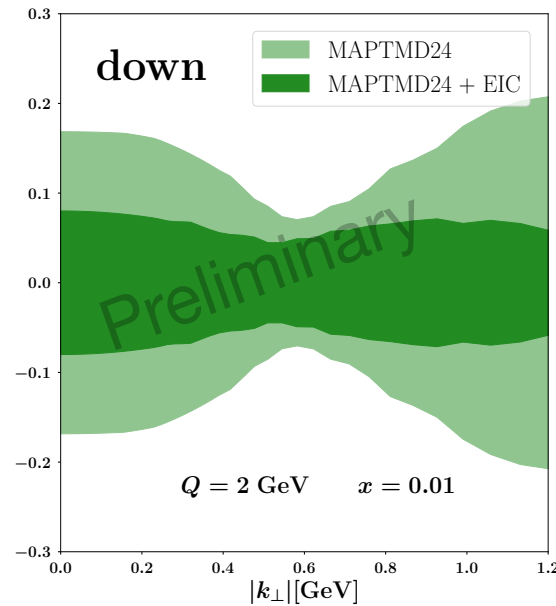
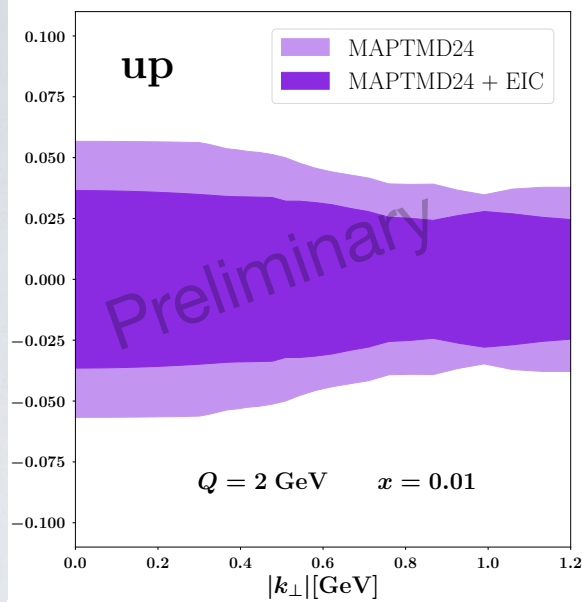
L. Rossi, Ph.D. Thesis, in preparation

# The EIC impact: all energies, $x = 0.01$

$$\frac{\text{TMD}^q - \langle \text{TMD}^q \rangle}{\langle \text{TMD}^q \rangle}$$

MAPTMD24	# pts.	lumi [fb <sup>-1</sup> ]
2031		
<b>EIC</b>		
5x41	1273	2.85
10x100	1611	51.3
18x275	1648	10

(conditions of simulation campaign in May)

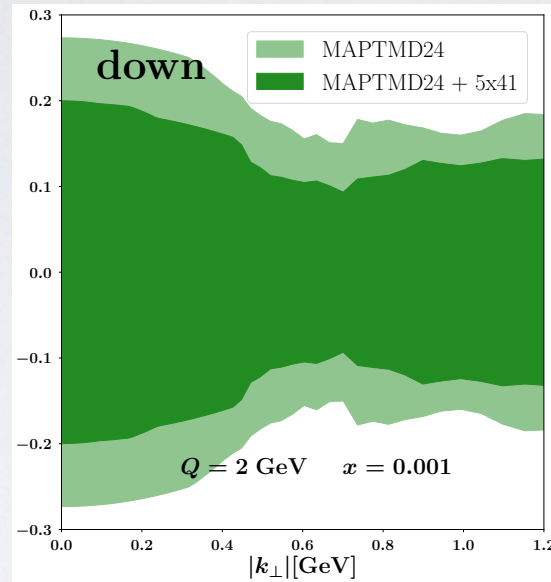
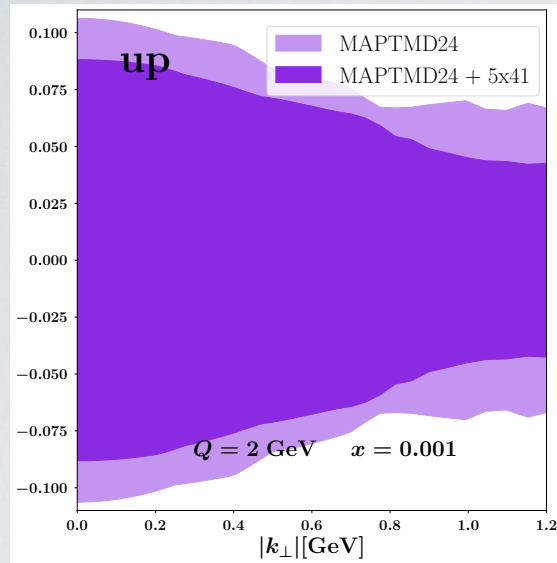


L. Rossi, Ph.D. Thesis, in preparation

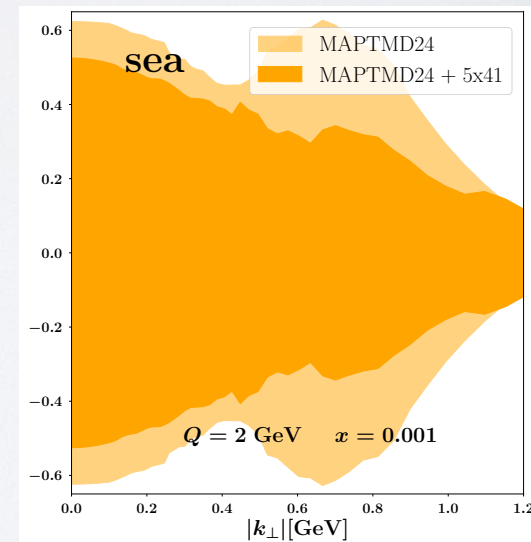
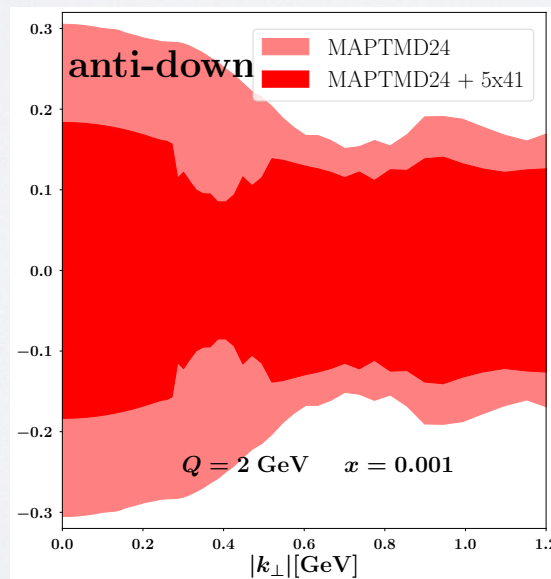
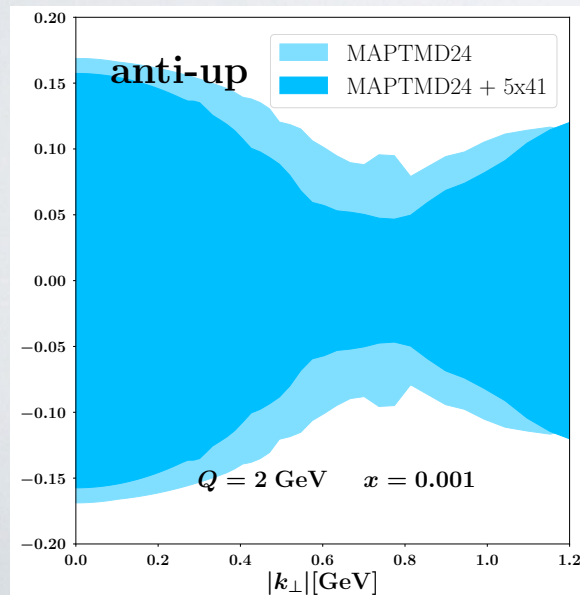


# The EIC impact: $5 \times 41$ , $x = 0.001$

$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$



	MAPTMD24	2031	
<b>EIC</b>	<b>5x41</b>	<b># pts.</b>	<b>lumi [fb<sup>-1</sup>]</b>
		1273	2.85

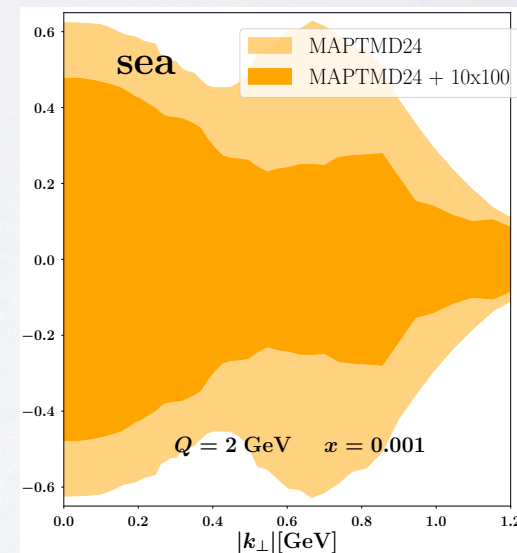
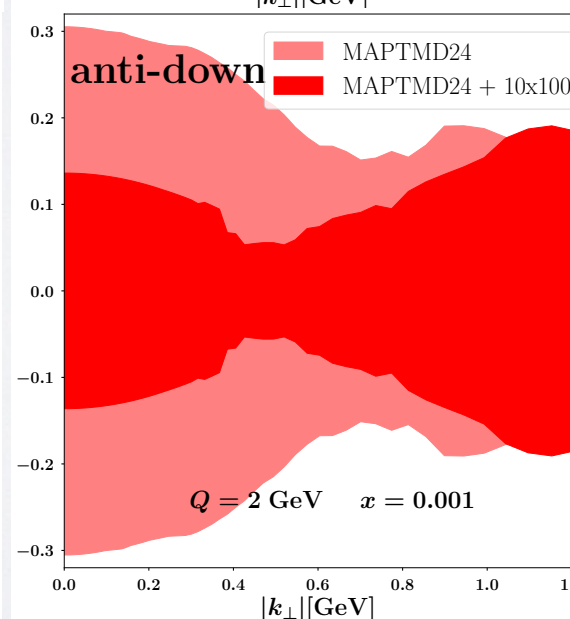
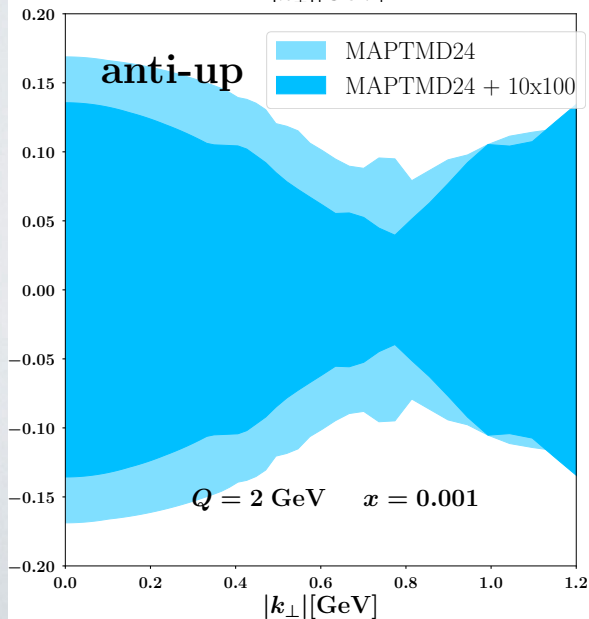
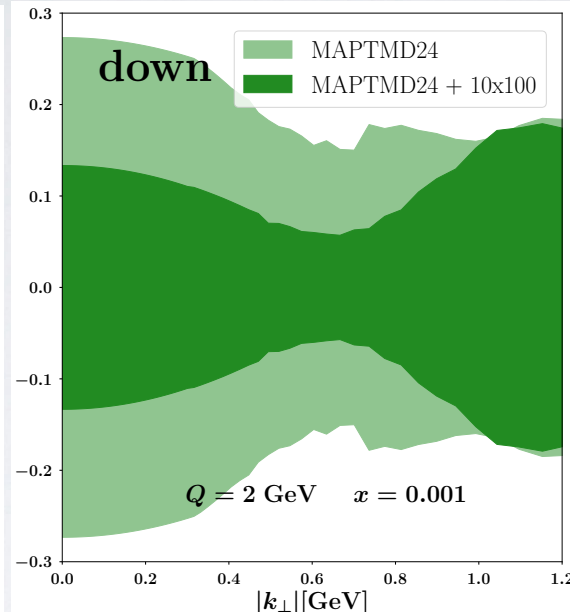
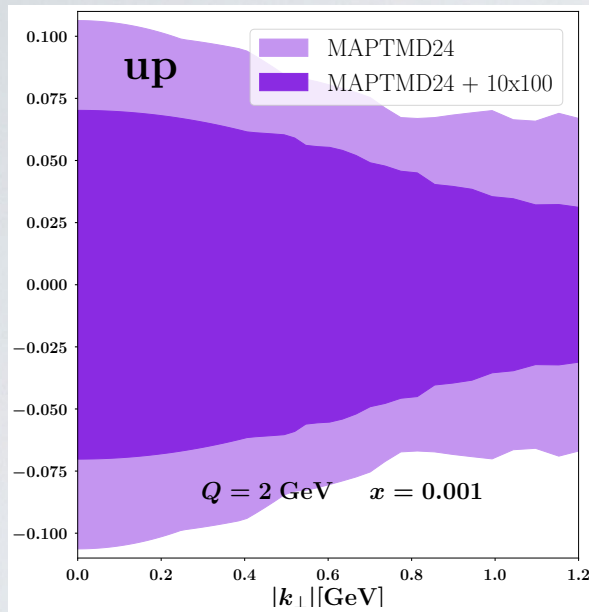


# The EIC impact: 10x100, $x = 0.001$

$$\frac{\text{TMD}_q - \langle \text{TMD}_q \rangle}{\langle \text{TMD}_q \rangle}$$

<b>MAPTMD24</b>	2031	
<b>EIC</b>	<b># pts.</b>	<b>lumi [fb<sup>-1</sup>]</b>
10x100	1611	51.3

(conditions of simulation campaign in May)



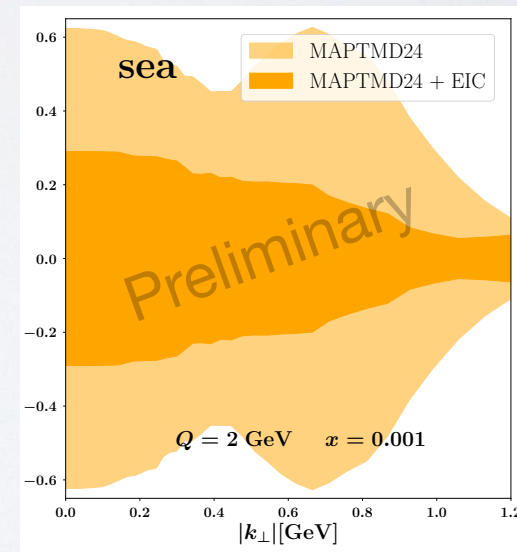
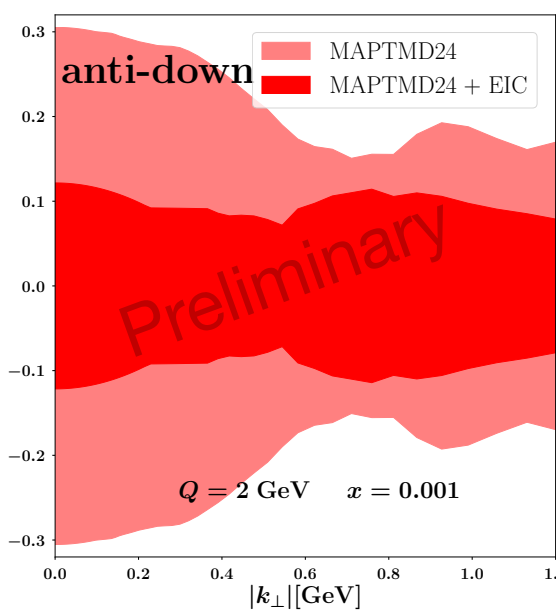
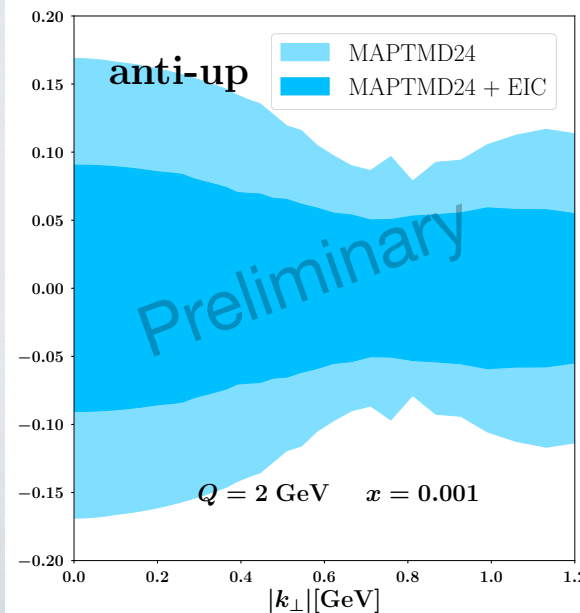
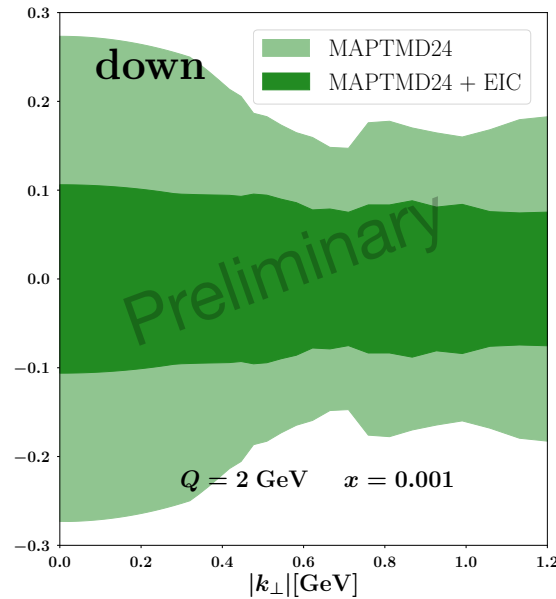
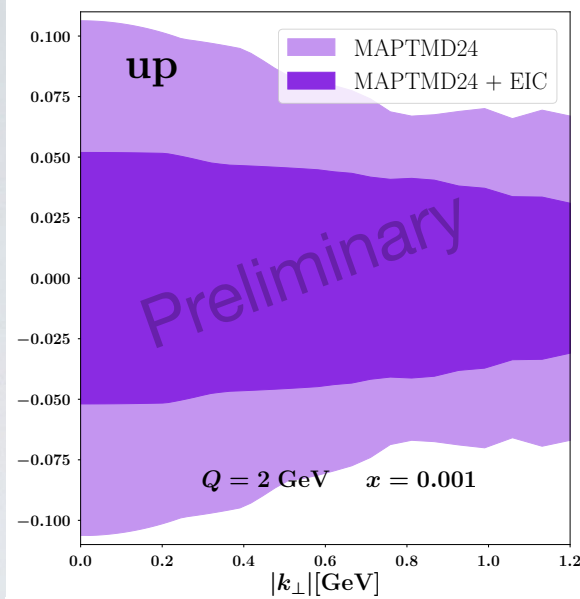
L. Rossi, Ph.D. Thesis, in preparation

# The EIC impact: all energies, $x = 0.001$

$$\frac{\text{TMD}^q - \langle \text{TMD}^q \rangle}{\langle \text{TMD}^q \rangle}$$

	MAPTMD24	2031	EIC	# pts.	lumi [fb <sup>-1</sup> ]
			5x41	1273	2.85
			10x100	1611	51.3
			18x275	1648	10

(conditions of simulation campaign in May)



L. Rossi, Ph.D. Thesis, in preparation