Theory: Opportunities for first EIC physics

P. Zurita

ePIC collaboration meeting
Jan. 20-24, 2025

Outline

- ⚔️ Disclaimer
- ⚔️ Observables that we know “well”
- ⚔️ Observables about which we know at least something
- ⚔️ Observables we know nothing about
- ⚔️ Summary

Disclaimer

	Species	Energy	Luminosity (fb^{-1})	e polarization	p/A polarization
Year 1	e+Ru or e+Cu	10 x 115	0.9	N/A	N/A
Year 2	e+d (21 weeks)	10 x 130	9.2	N/A	N/A
	e+p (5 weeks)	10 x 130	0.95 - 1.03	N/A	trans?
Year 3	e+p	10 x 130	4.95 - 5.33	N/A	trans & long
Year 4	e+Au (13 weeks)	10 x 100	0.42	N/A	N/A
	e+p (13 weeks)	10 x 250	3.09 - 4.59	N/A	trans & long
Year 5	e+Au (13 weeks)	10 x 100	0.42	N/A	N/A
	e+^{3}He (13 weeks)	10 x 166	4.33	N/A	trans & long

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No electron polarization

No/little mention of TMD/GPD

Not everything in the YR is included here

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* **don’t believe these results**

Not everything in the YR is included here

with YR filter

with YR filter

without YR filter

with YR filter

without perfect detector filter

Observables

that we know

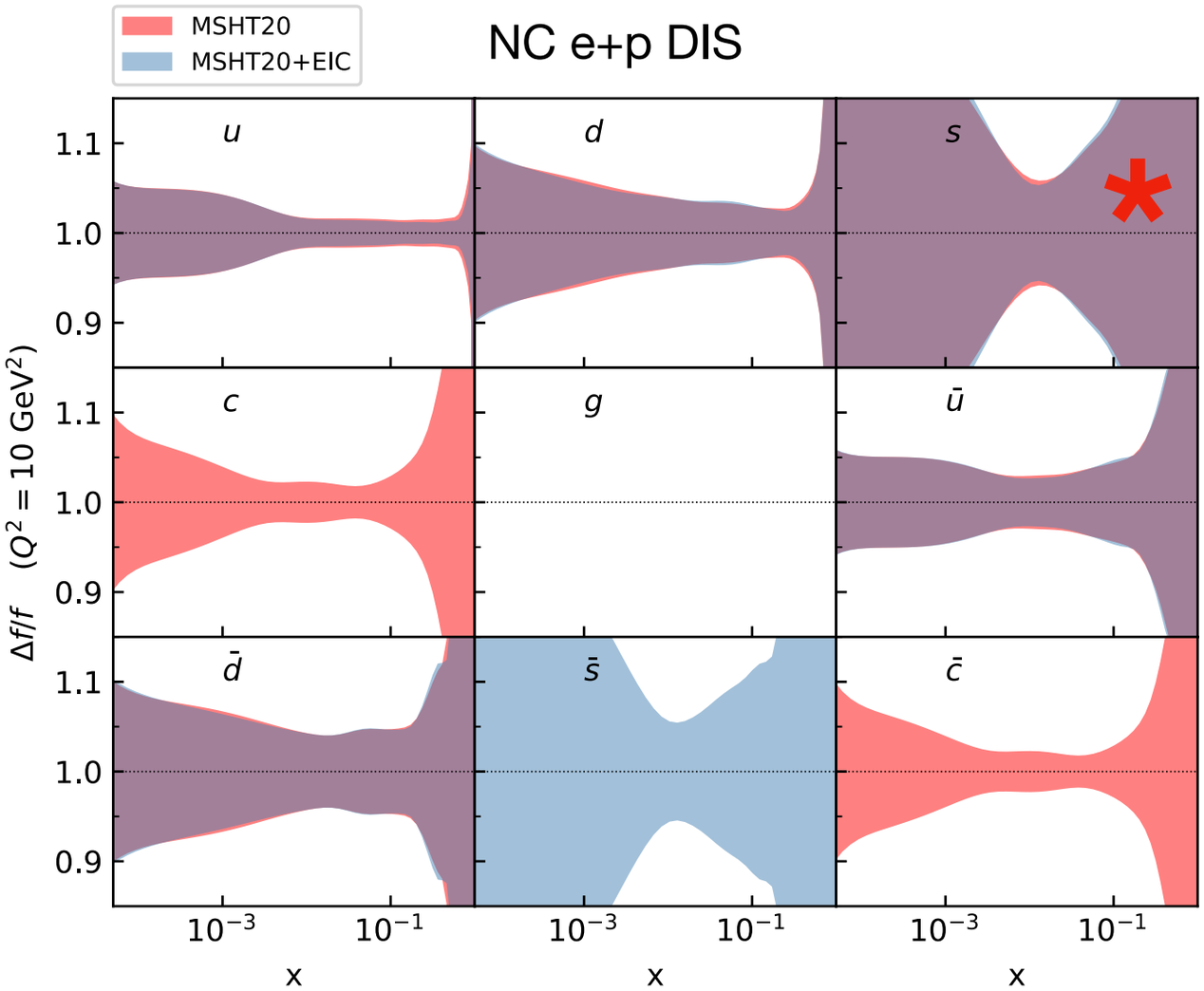
“well”

(but we can always improve)

e+p NC DIS for collinear proton PDFs

simulated in YR: $\mathscr{L}_{int} \sim 100\, fb^{-1}$ +CC, +NC e+d $\mathscr{L}_{int} \sim 10\, fb^{-1}$

expected : $\mathscr{L}_{int} \sim 10\, fb^{-1}$



Results depend strongly on the PDF set used

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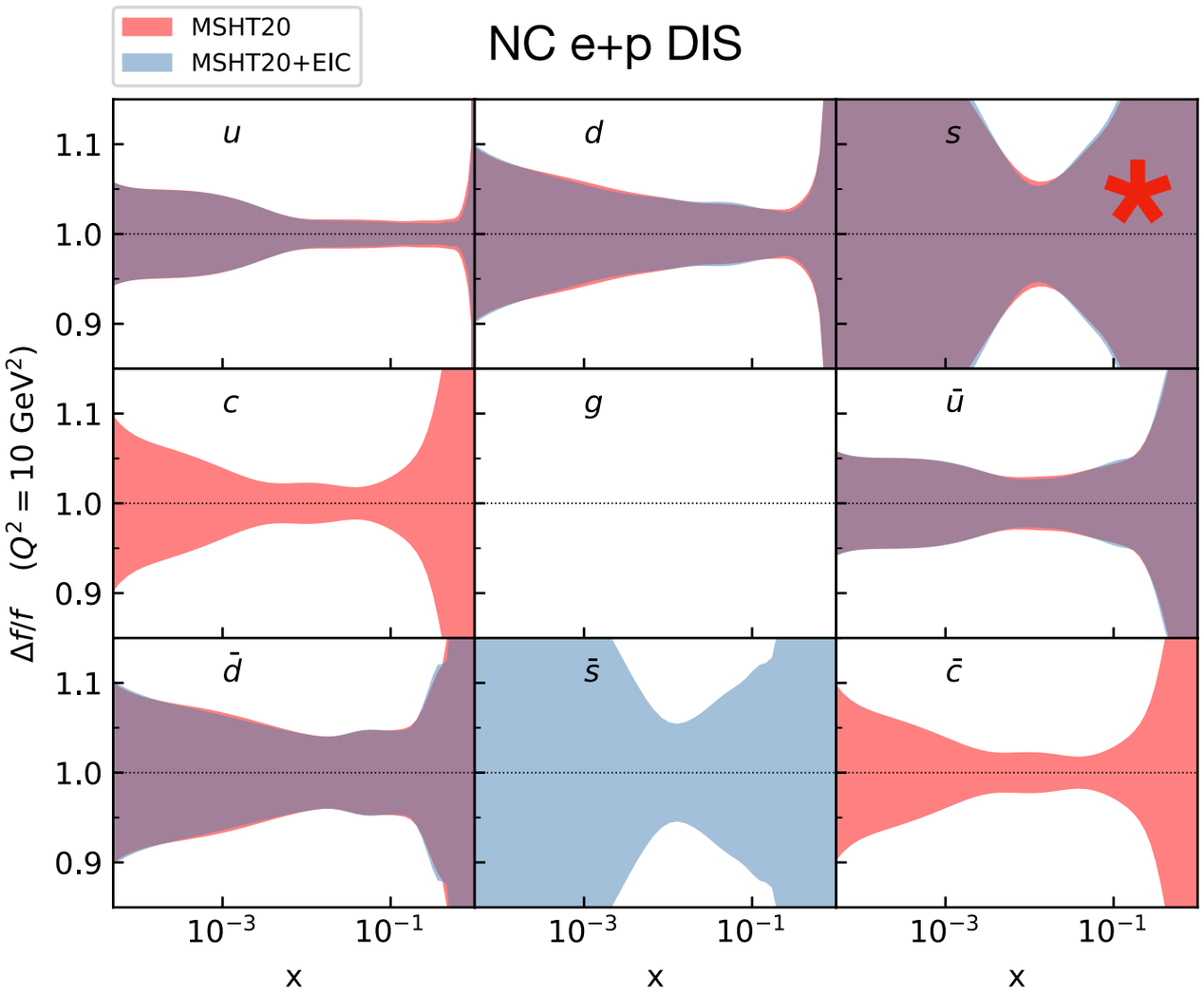

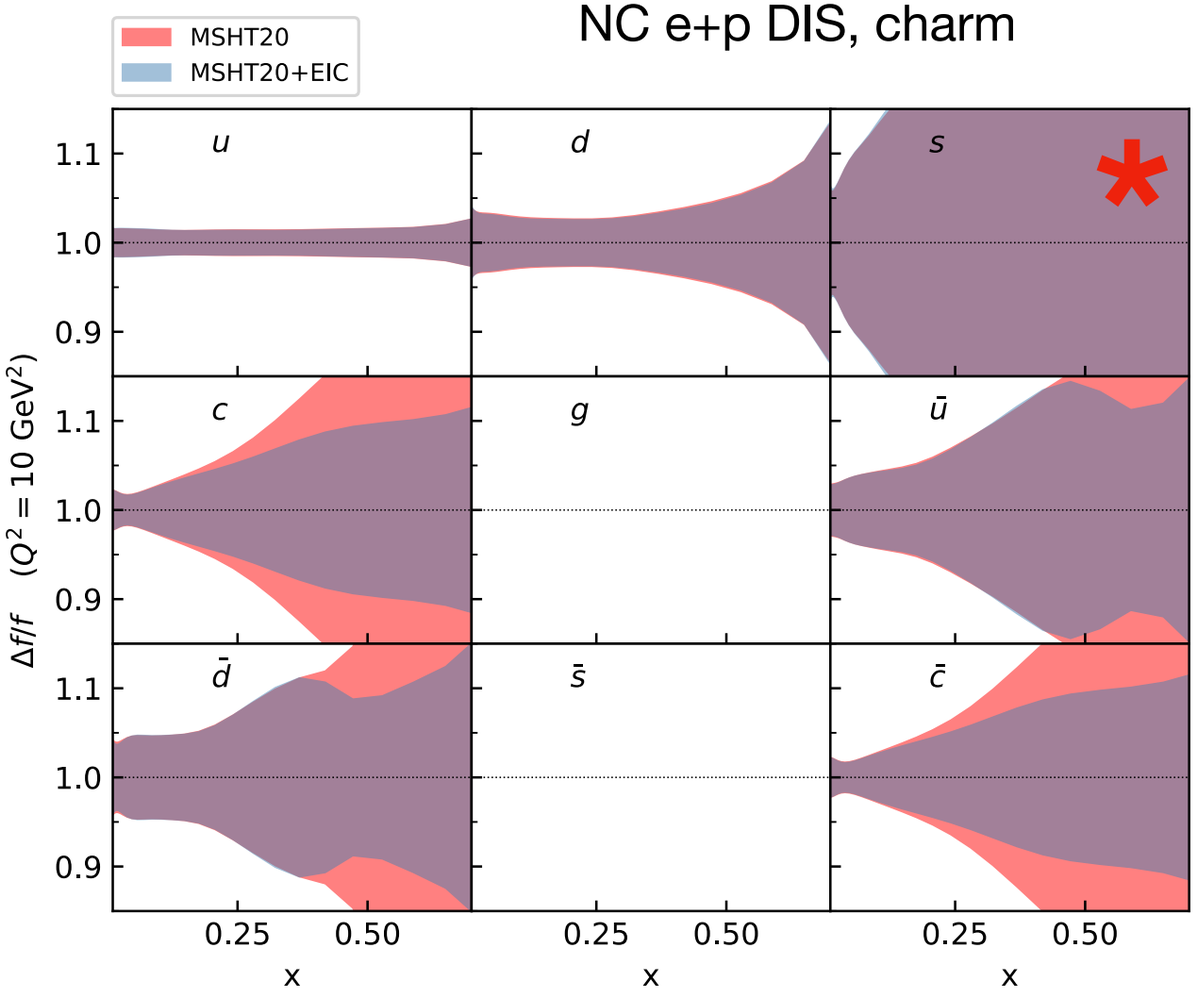

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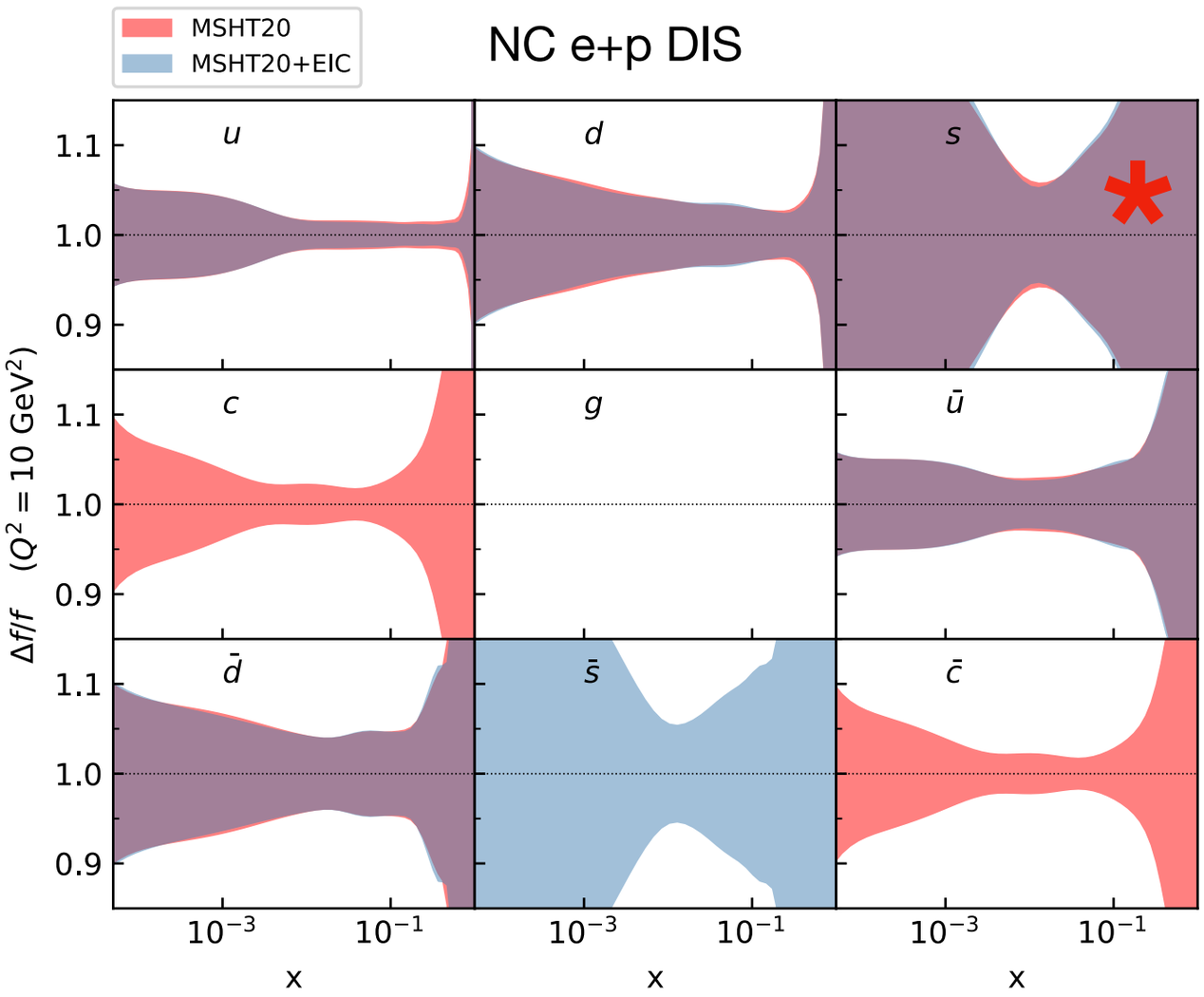

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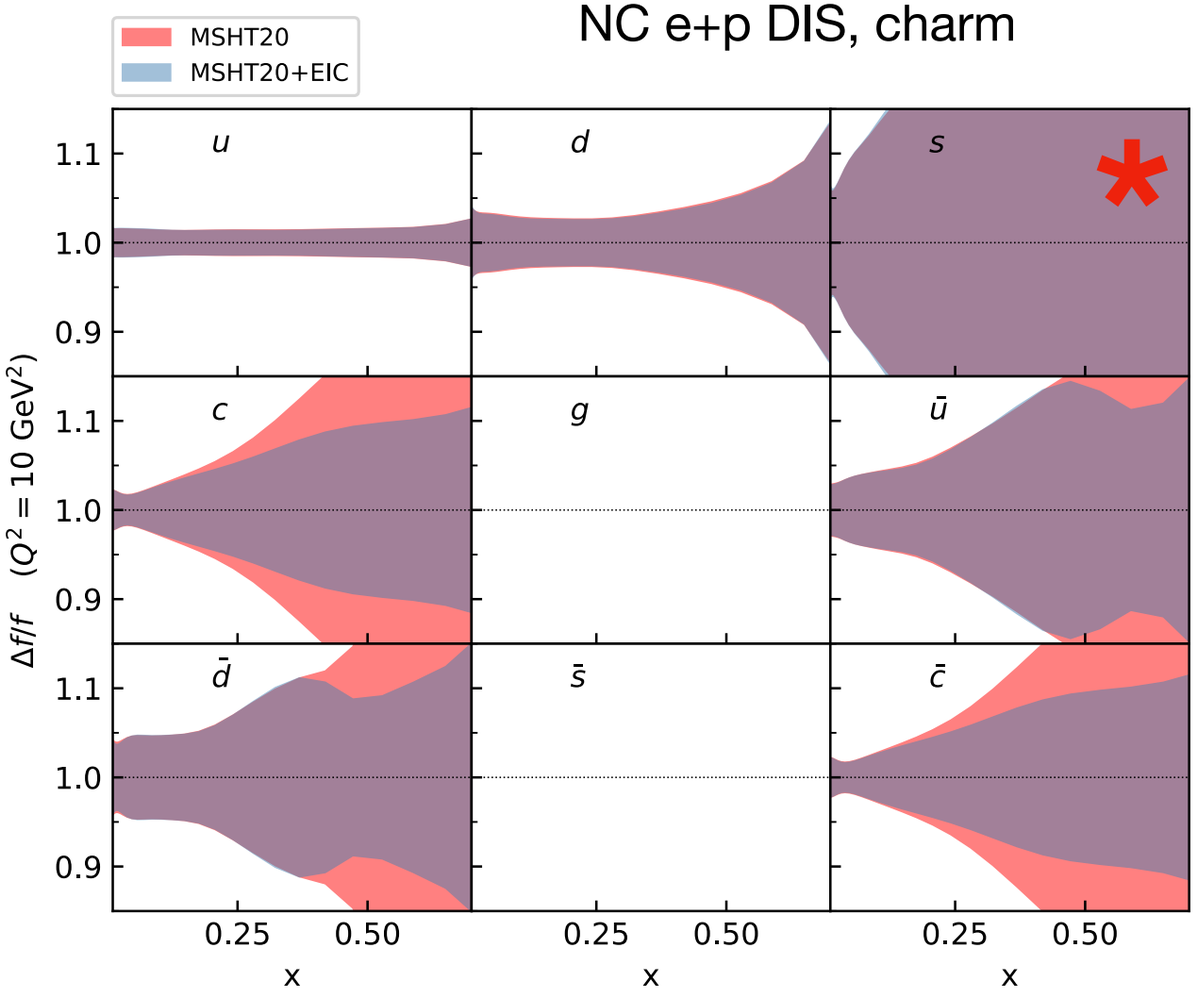

⚔ (double) tagged “free” neutron

⚔ N3LO (approx.) available

⚔ bottom possible?

☹ intrinsic charm unlikely

e+A NC DIS for nuclear PDFs

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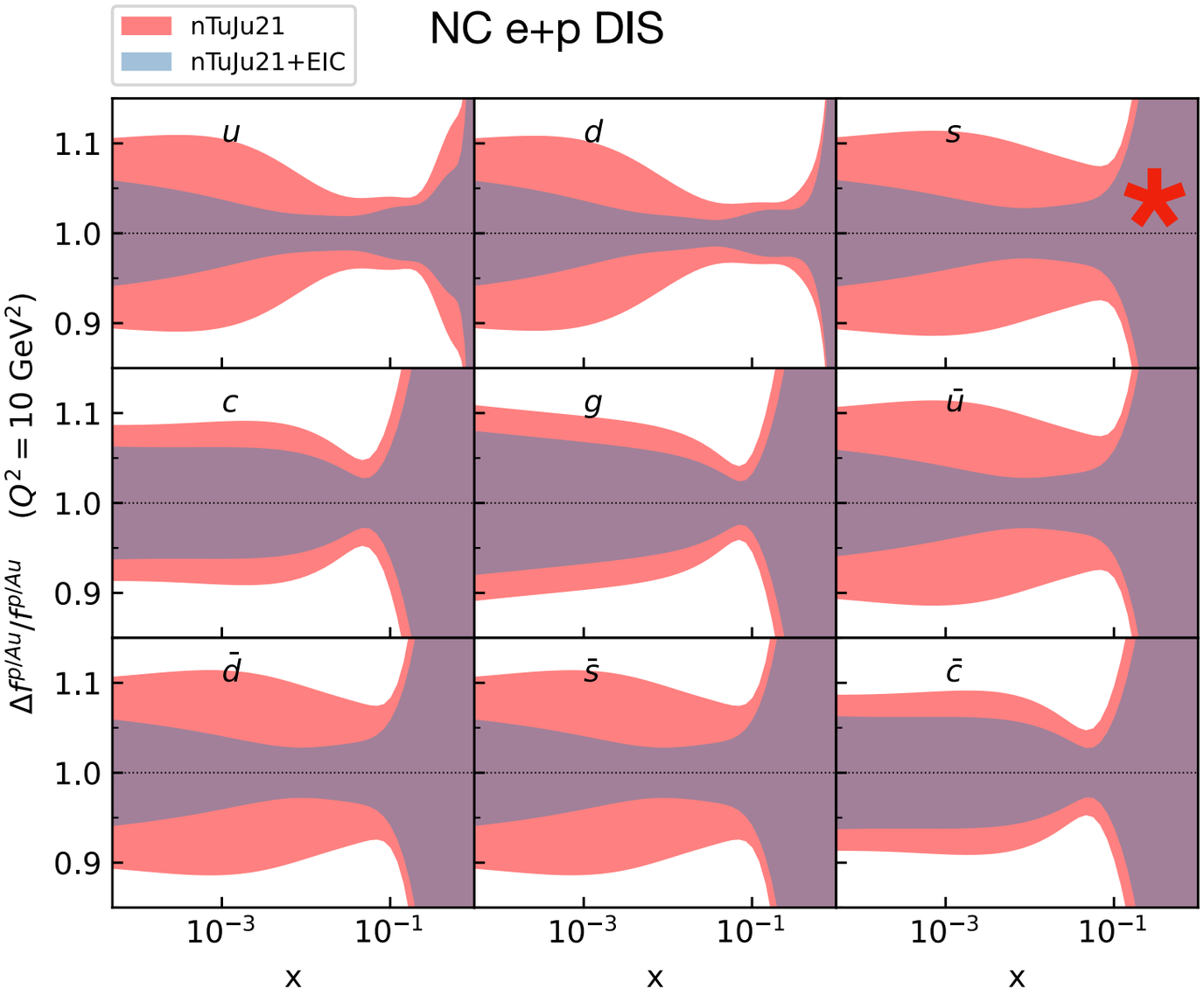
expected : $\mathscr{L}_{int} \sim 1\, fb^{-1}$



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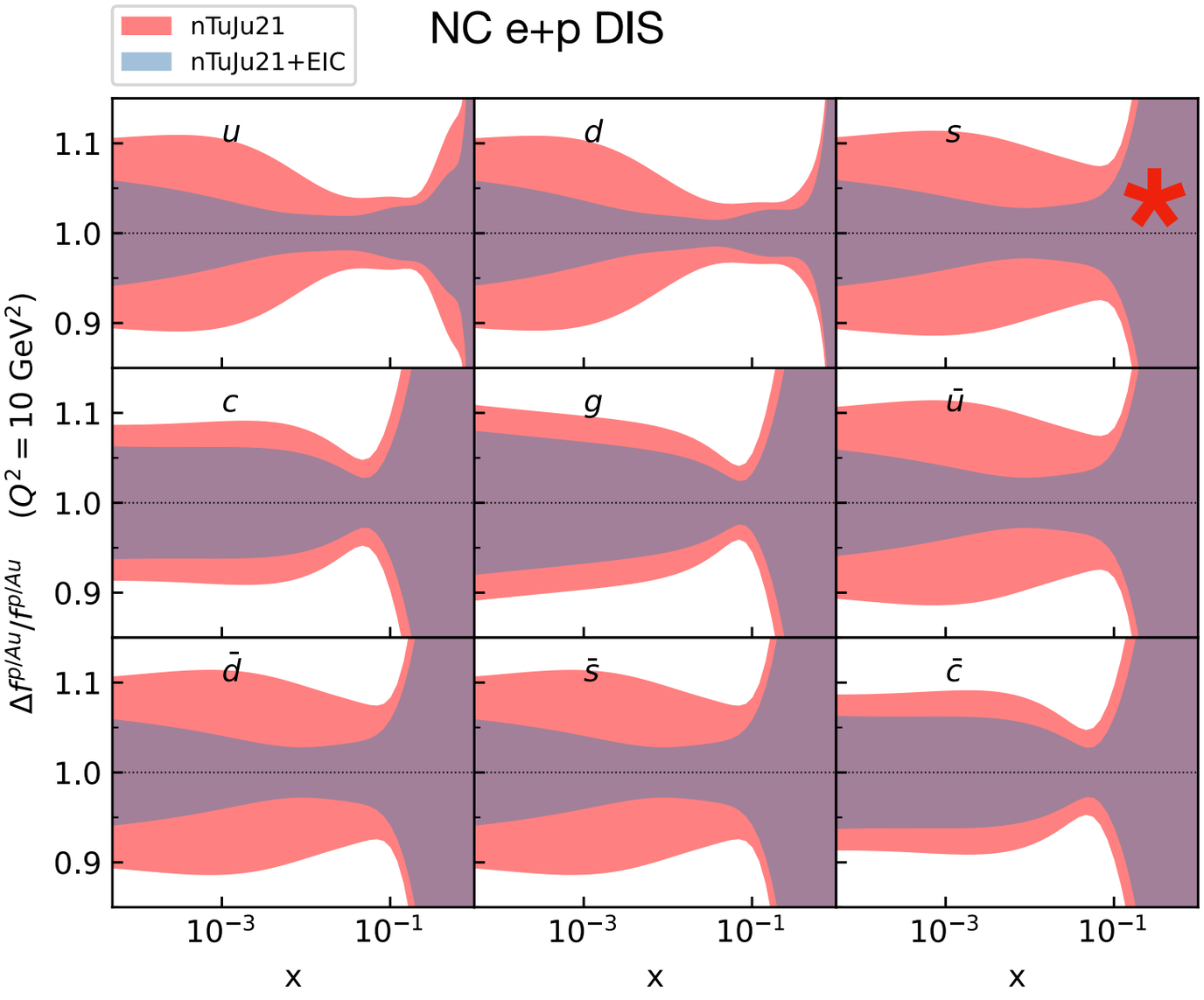

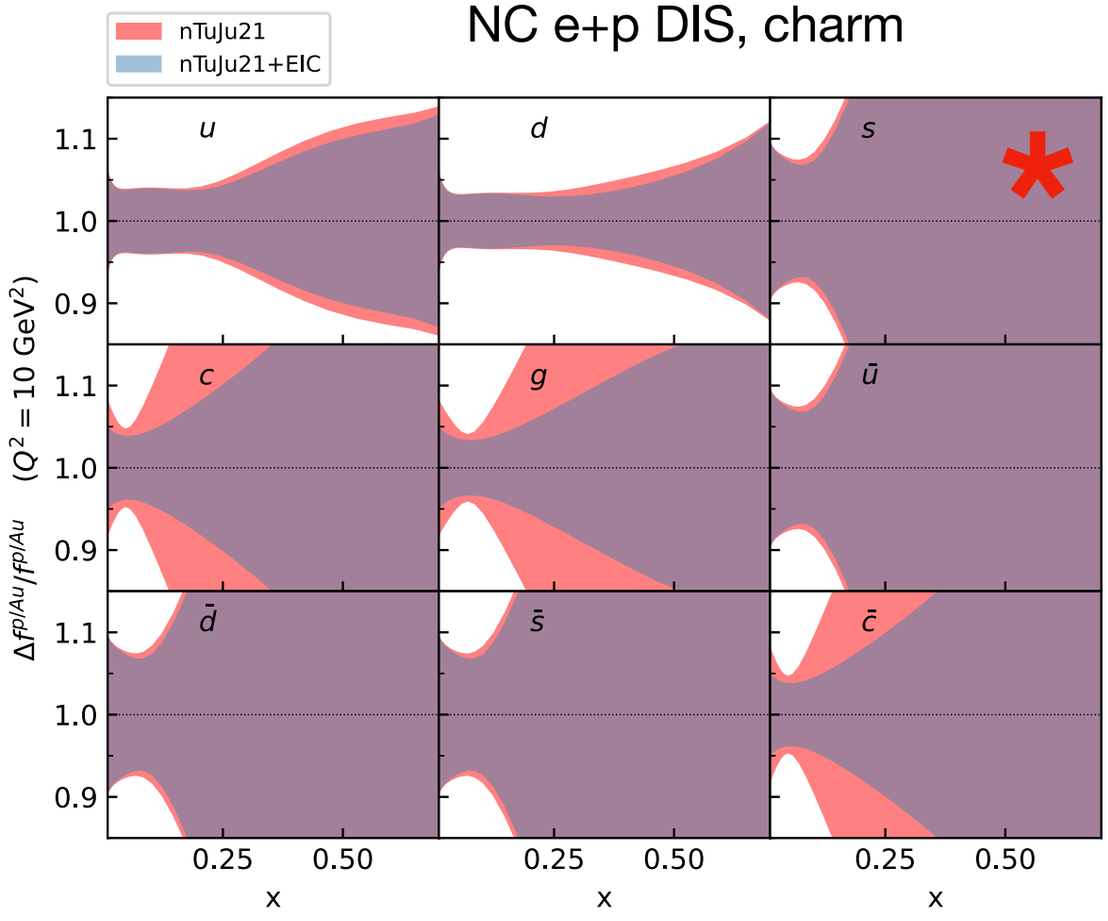

- ⚔️ light nuclei
- ⚔️ N3LO (approx.) available
- ⚔️ bottom possible?

- 😕 A-dependence not possible

SIDIS in e+p (light hadrons)

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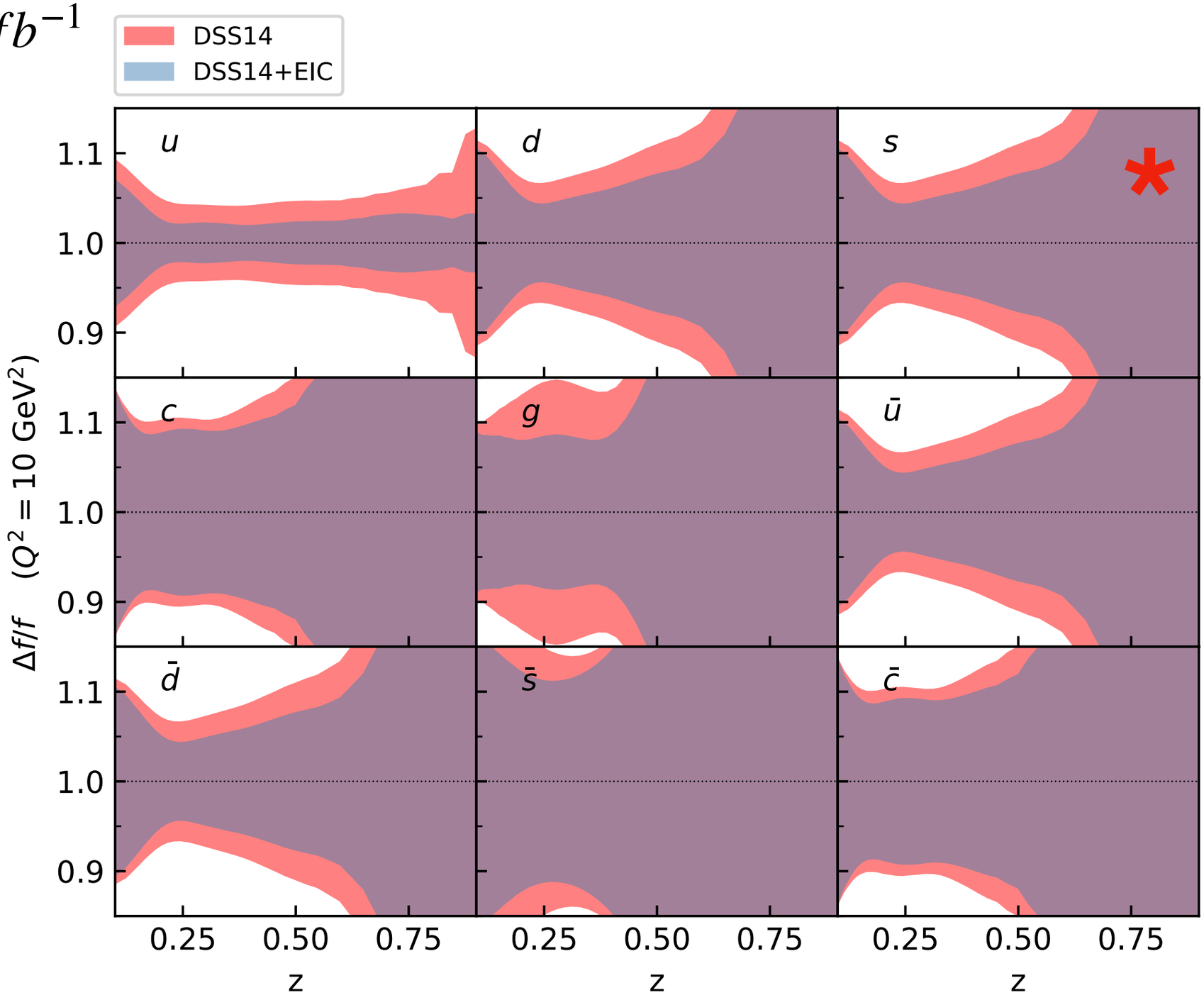

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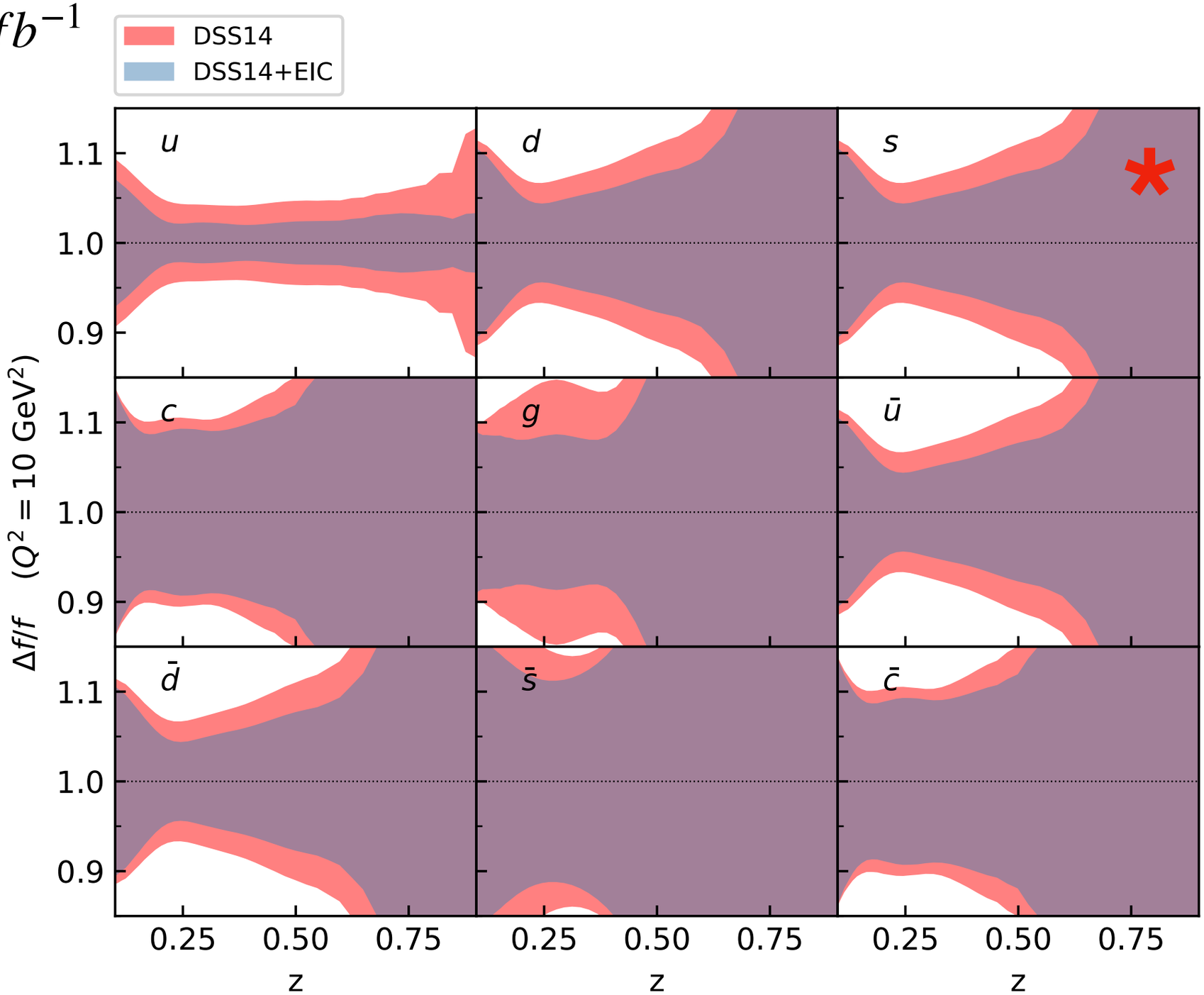

⚔ N2LO fully available

⚔ new COMPASS data (2410.12005 [hep-ex])

Observables about which we know at least something

(in no particular order)

SIDIS in e+A and nFFs (for light mesons)

Hadron formation in-medium for low energies (suppression at HERMES and JLAB)

Hadron formation outside the medium for EIC?

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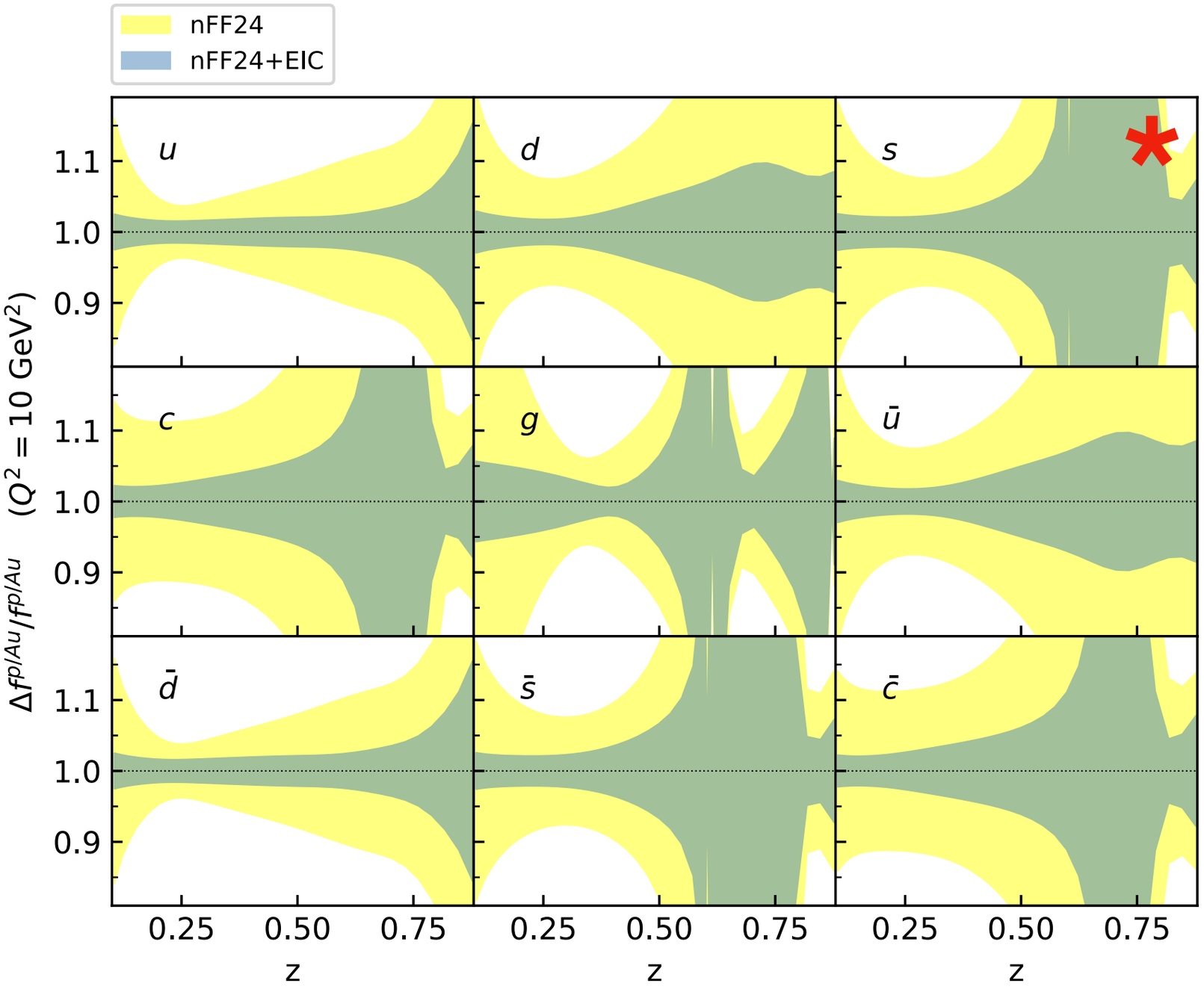


⚔ New (global) extraction of nFFs.

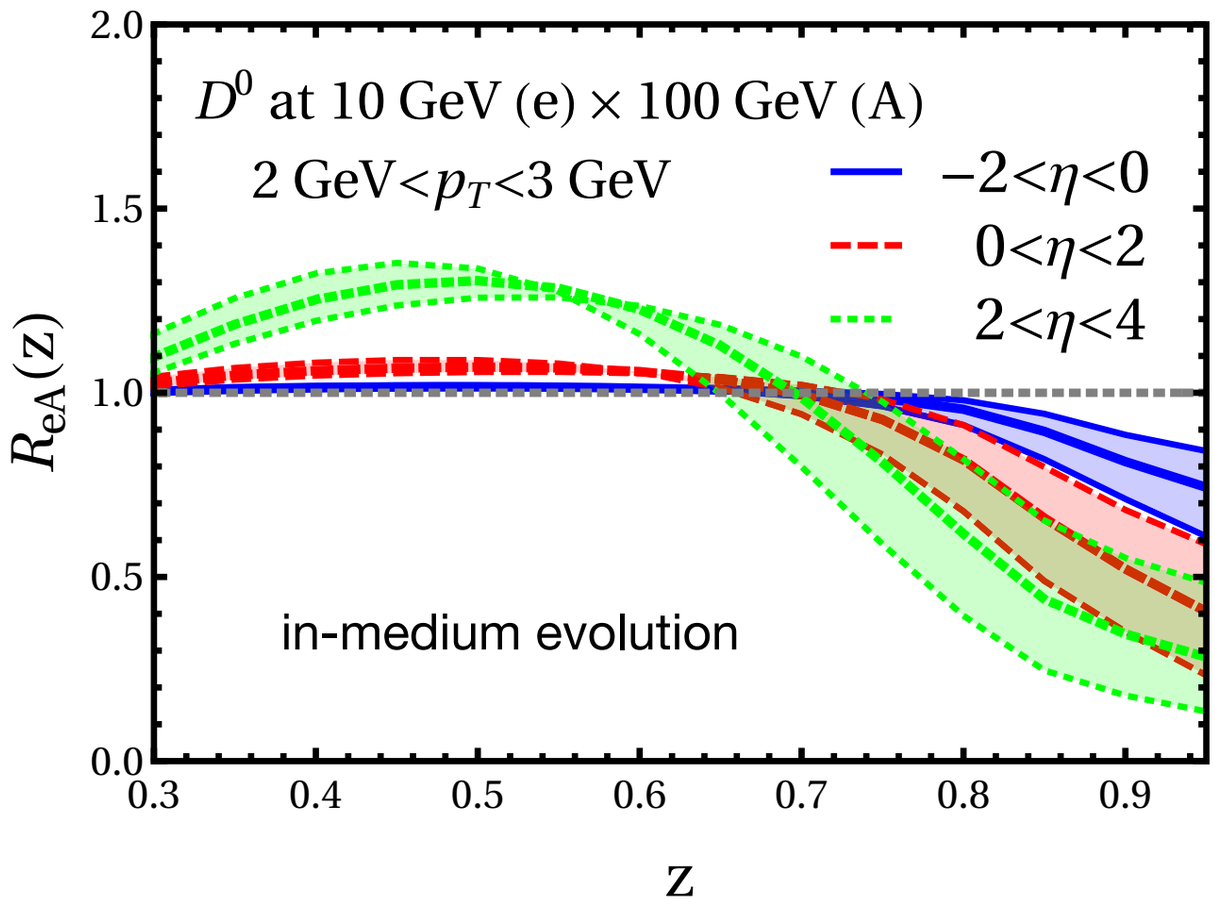
nFF24 by M. Doradau, R.T. Martinez, R. Sassot, M. Stratmann, 2411.08222 [hep-ph]

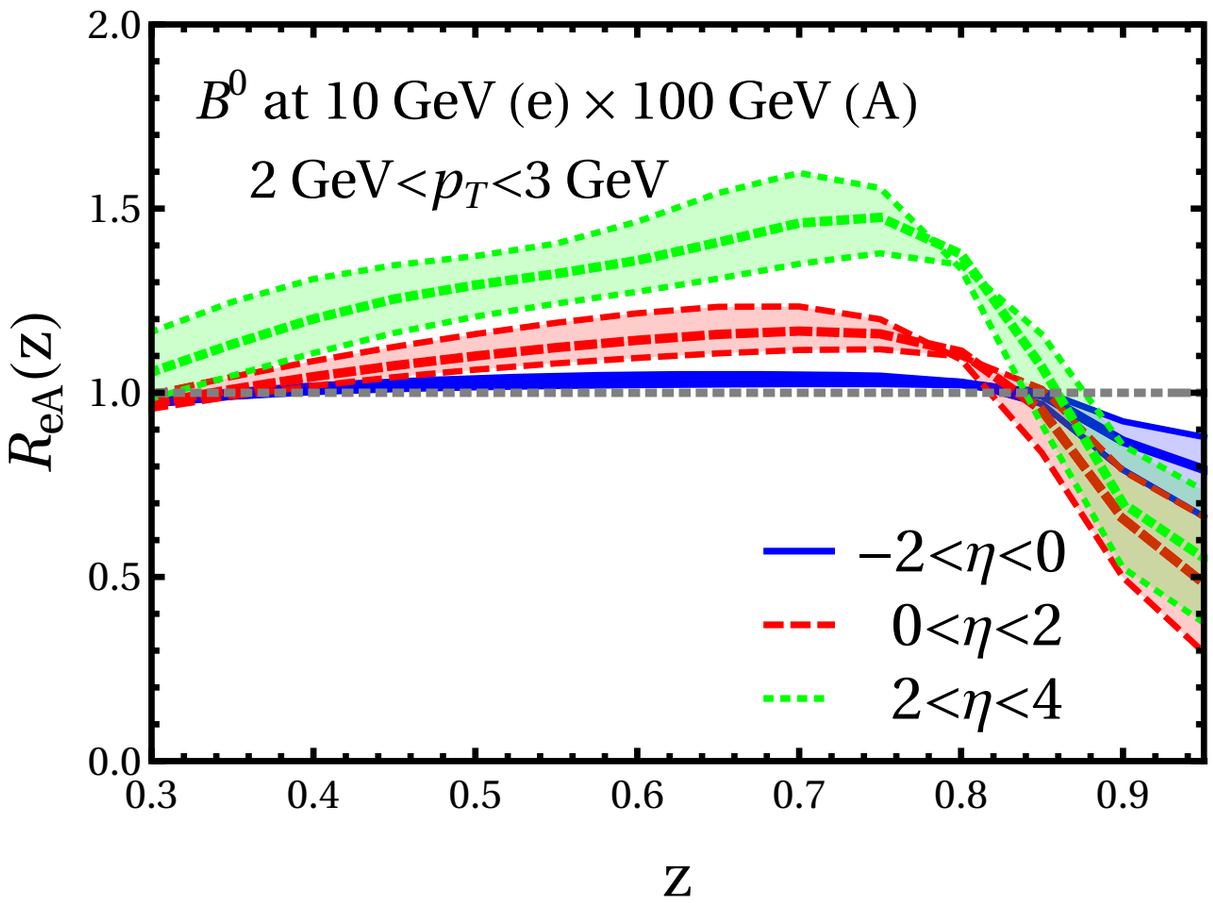
⚔ JLAB Fe data poorly described (w.r.t. Pb)

Heavy mesons in e+A

Longer formation times, hadronization expected inside the medium?

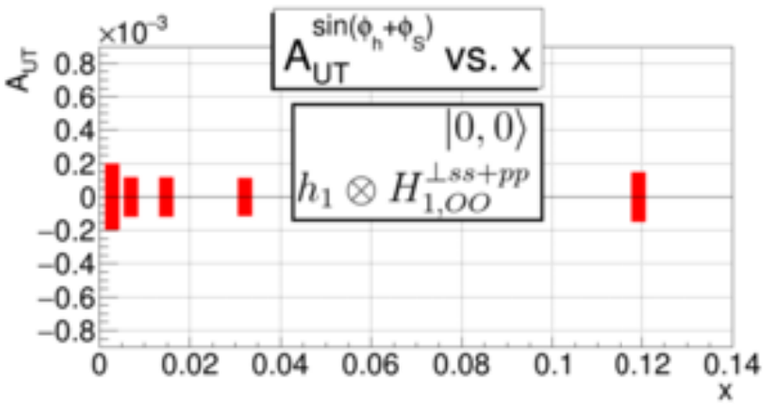
Discriminating power for different theoretical models.

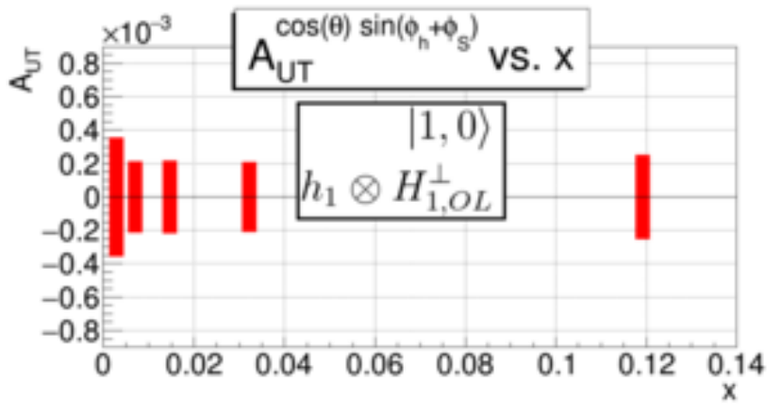


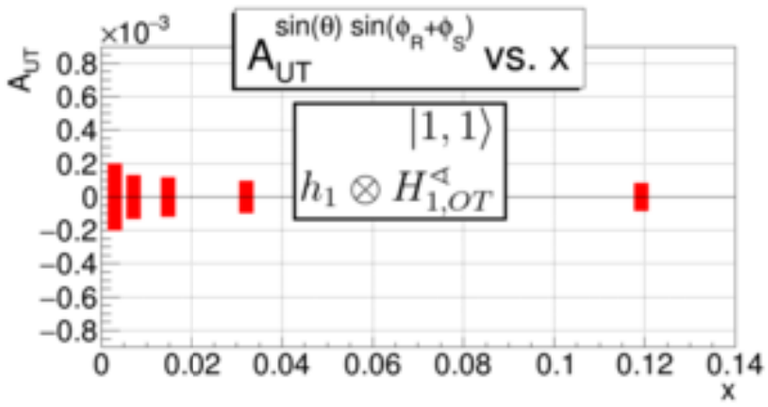


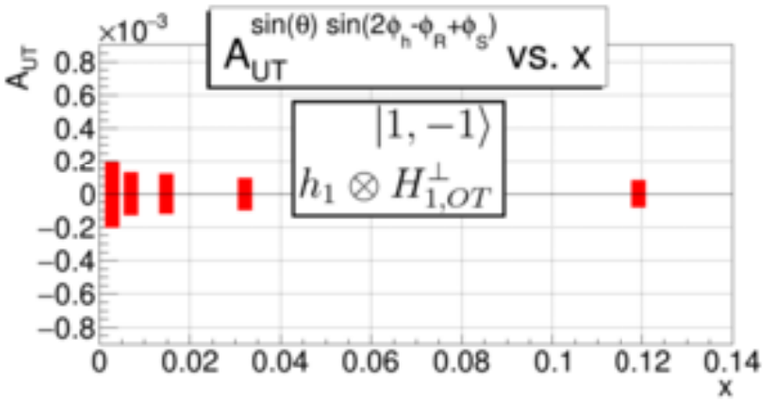
Di-hadron fragmentation functions

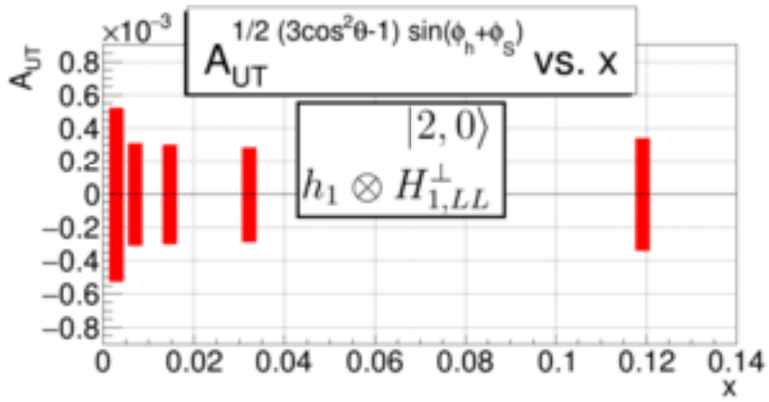
Mostly related with polarised collisions, but still some things can be done.

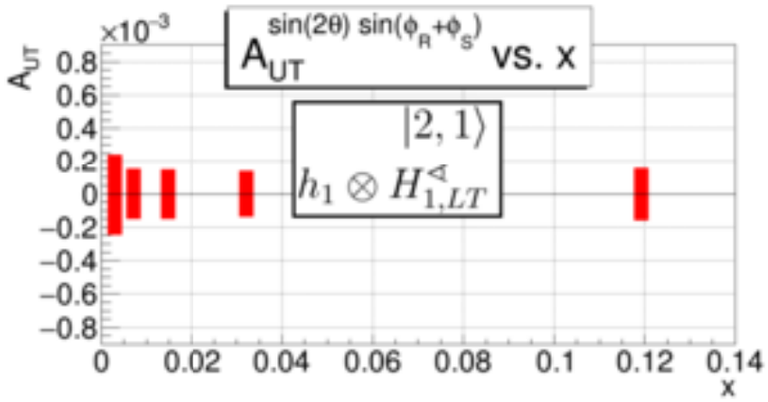


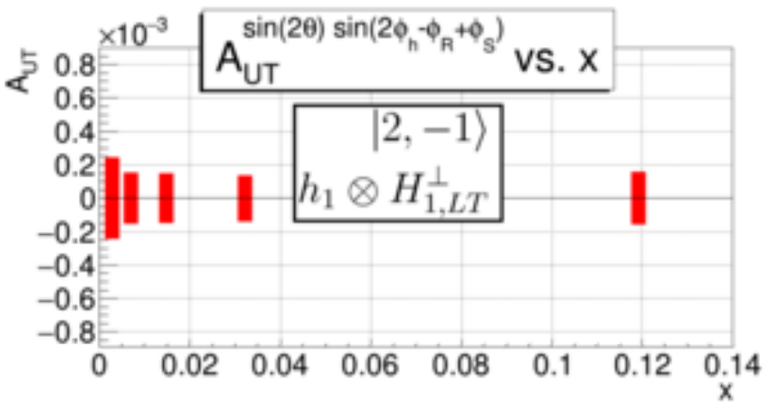


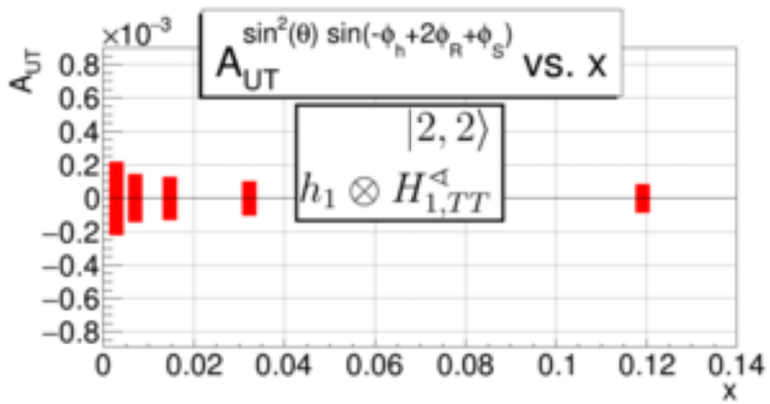


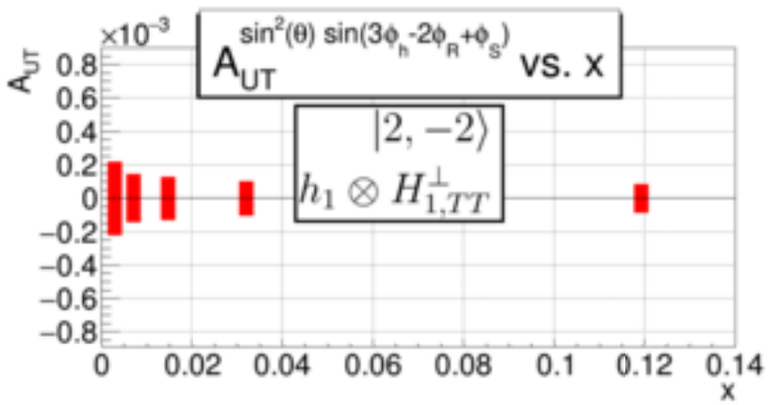








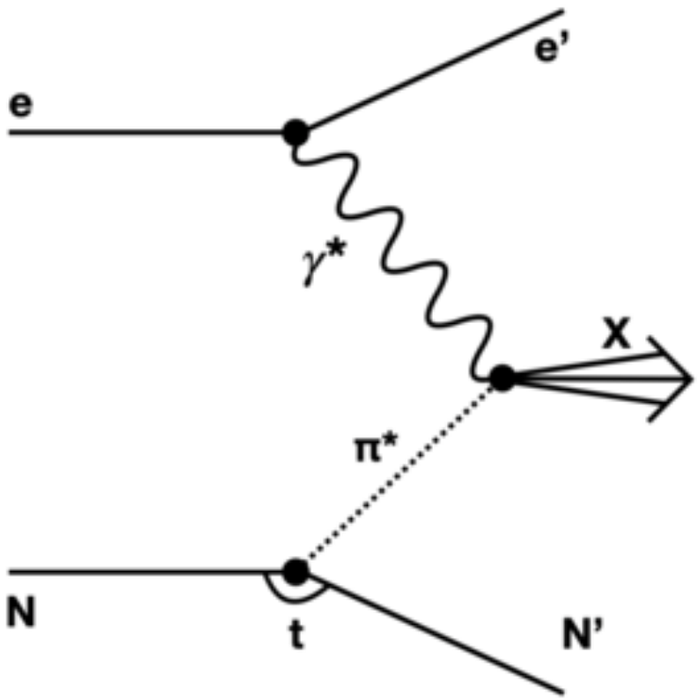




$ep^{\uparrow} \to e\pi^+\pi^- X$	5×41 GeV	10 fb^{-1}

expected: $\mathscr{L}_{int} \sim 10\, fb^{-1}$

Pion structure functions



SF YR: $\mathscr{L}_{int} \sim 100\, fb^{-1}$

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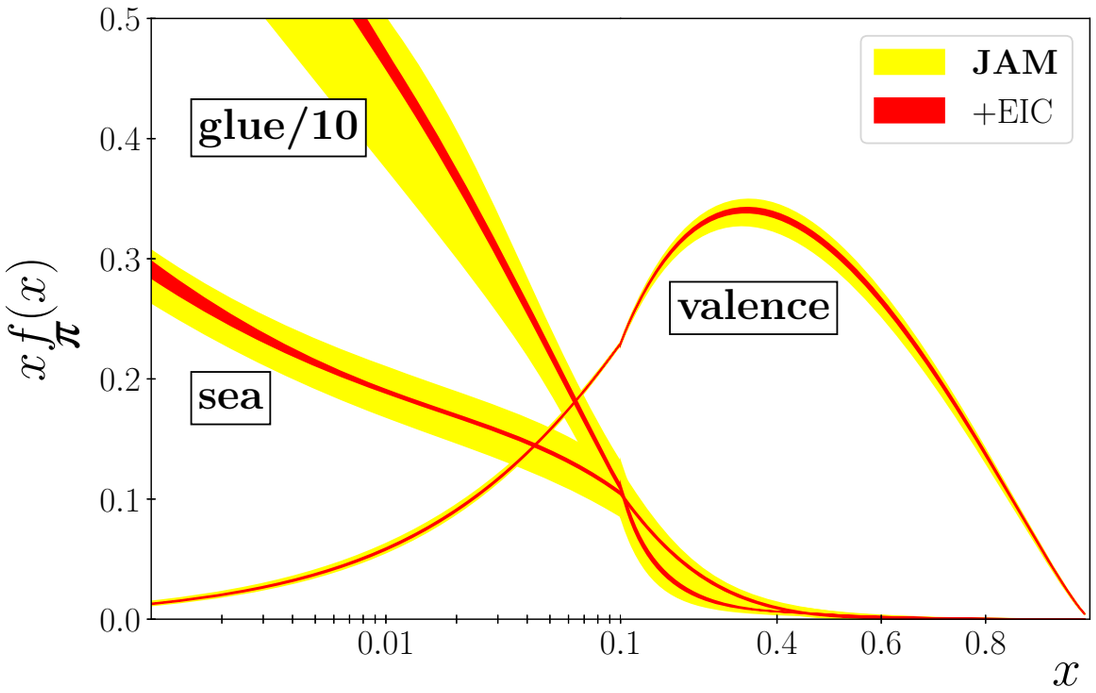
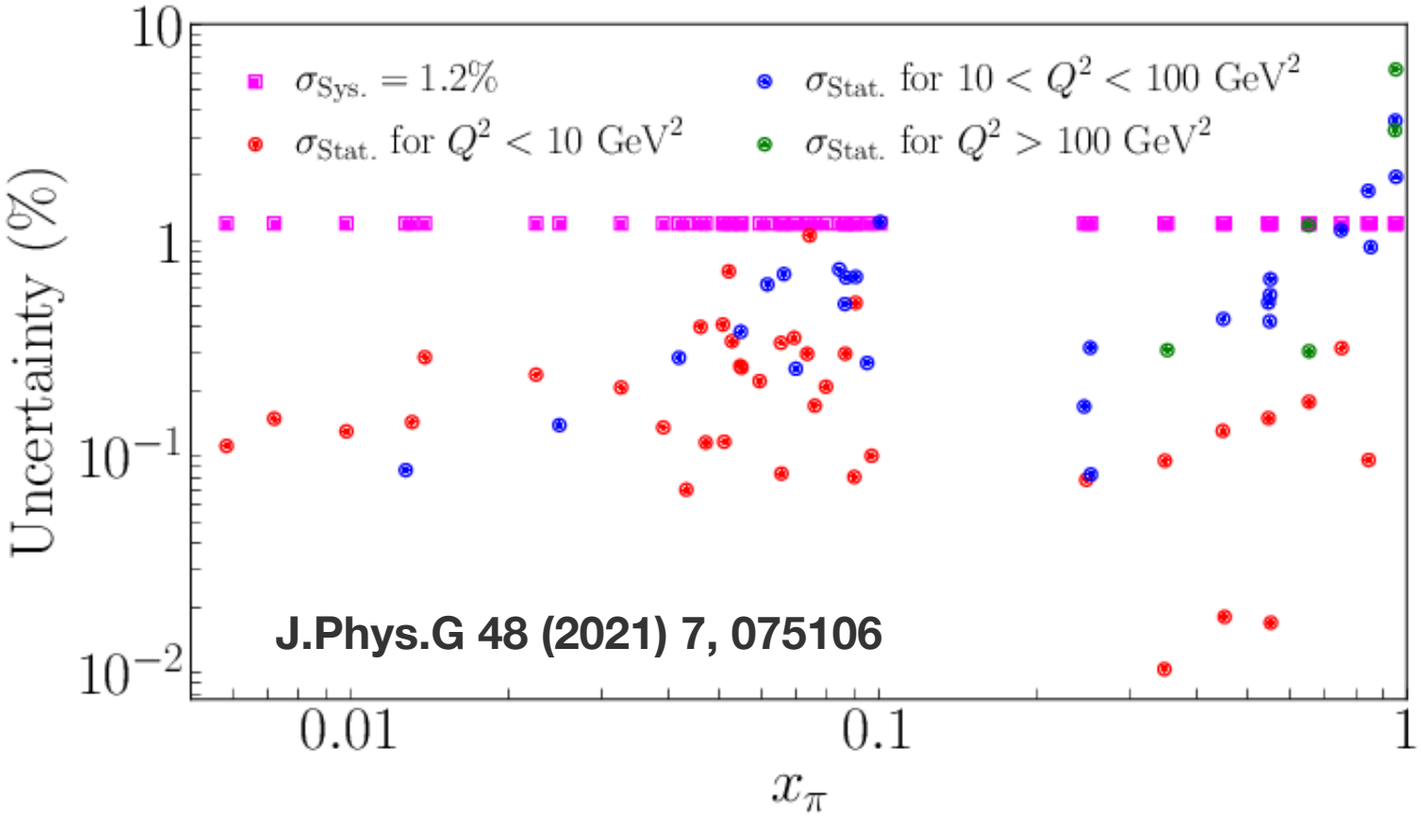
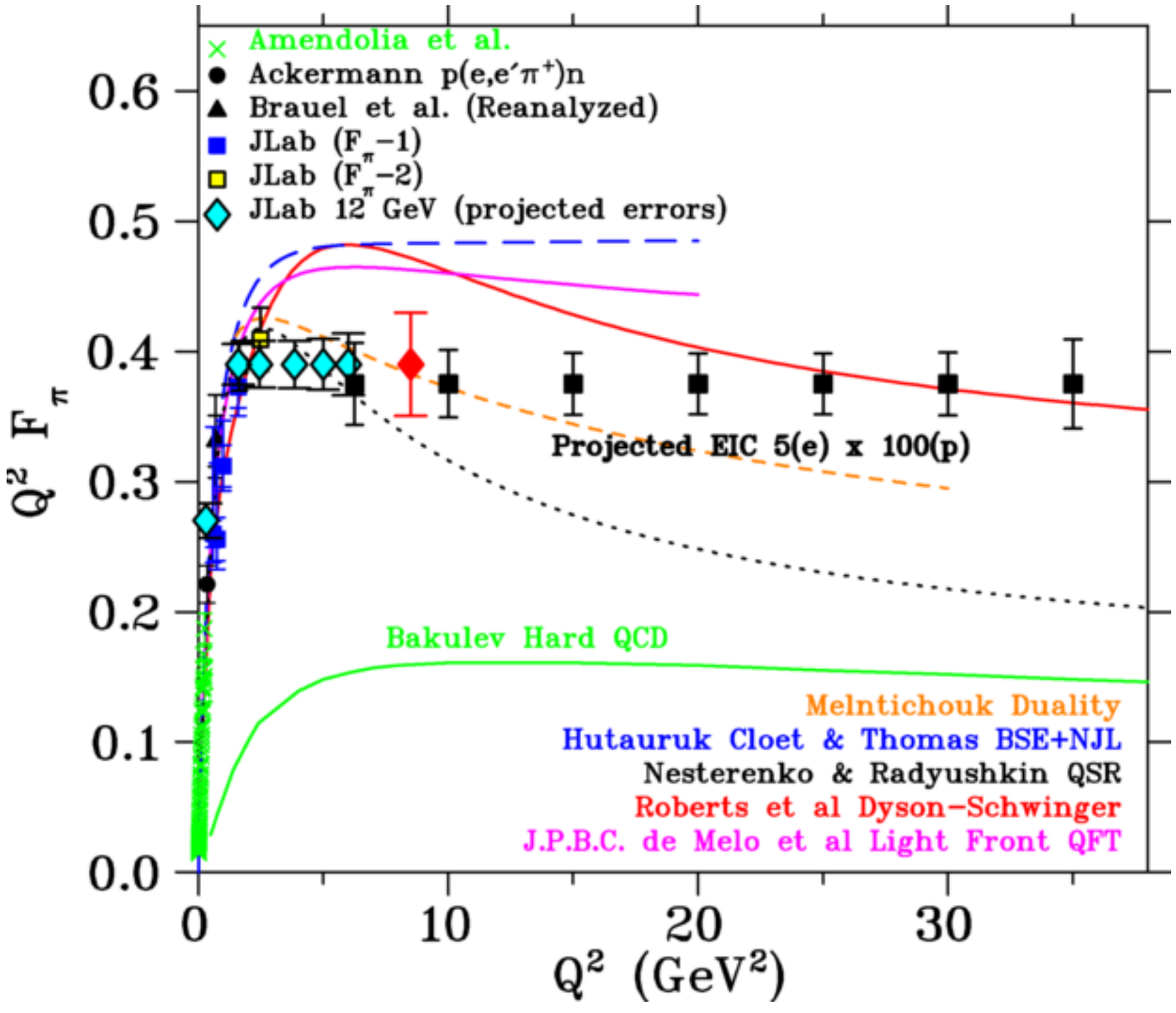




⚔️ Sullivan process proposed for pion GPDs

Pion form factors

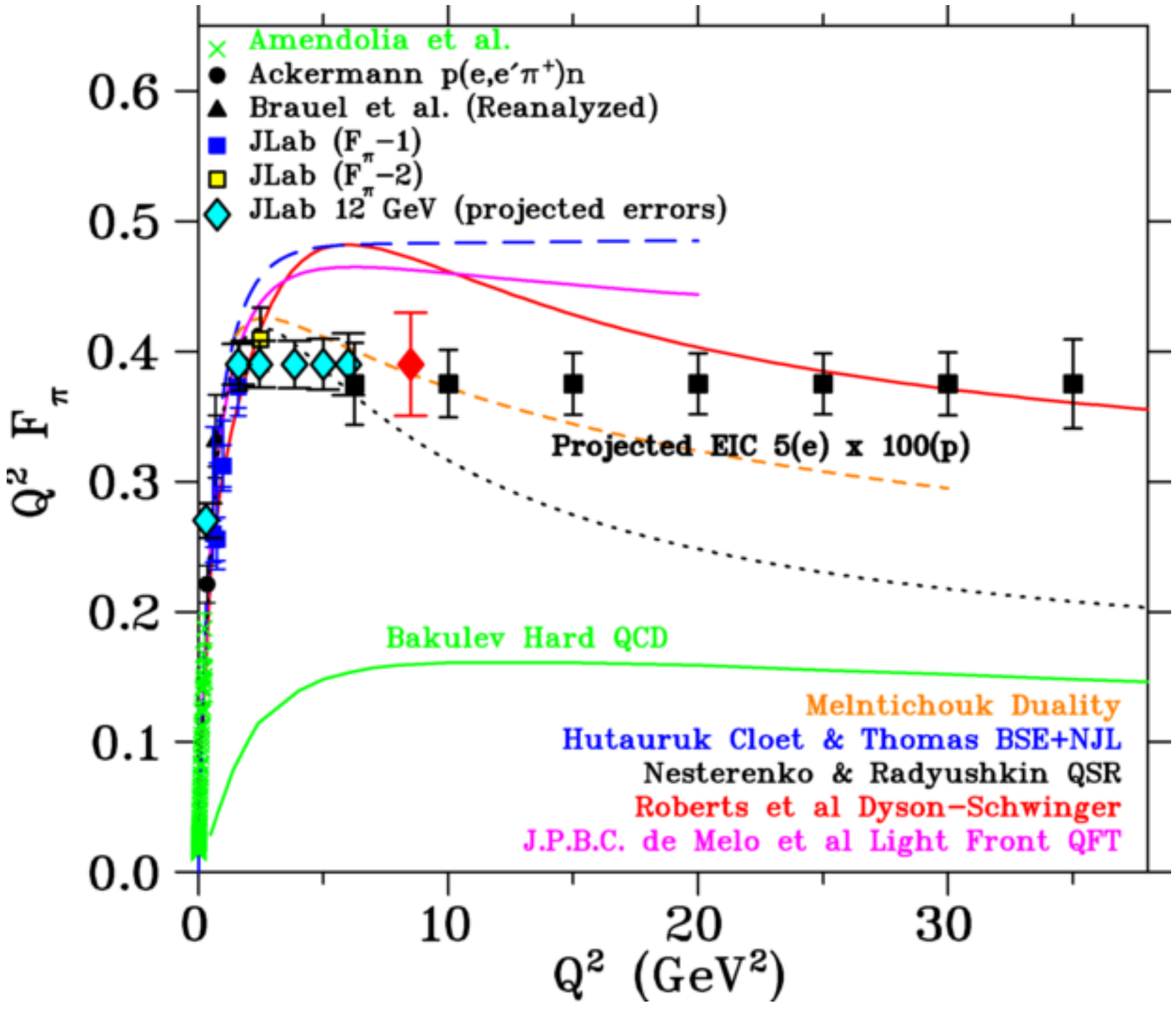
FF YR: $\mathscr{L}_{int} \sim 20\, fb^{-1}$



expected: $\mathscr{L}_{int} \sim 10\, fb^{-1}$

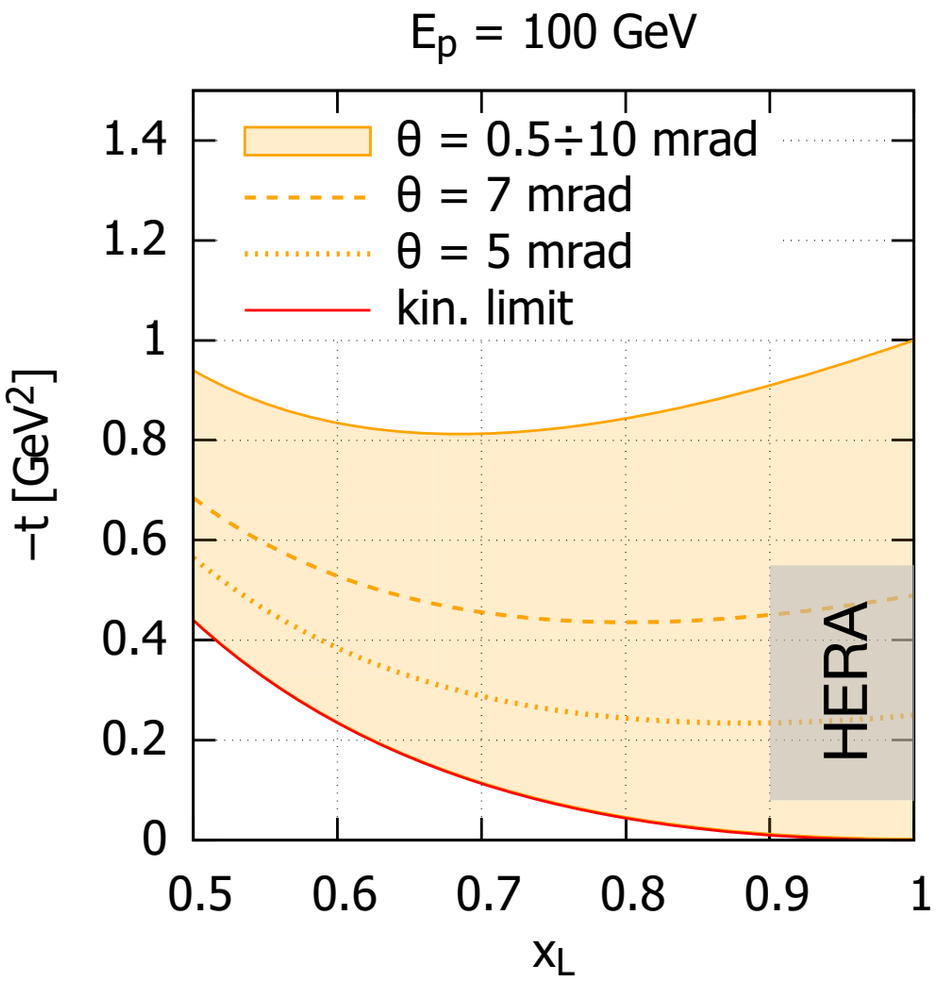
Pion form factors

FF YR: $\mathscr{L}_{int} \sim 20\, fb^{-1}$



⚔️ Also possible to measure nucleon form factors

Inclusive diffraction for DPDFs



access to F_L

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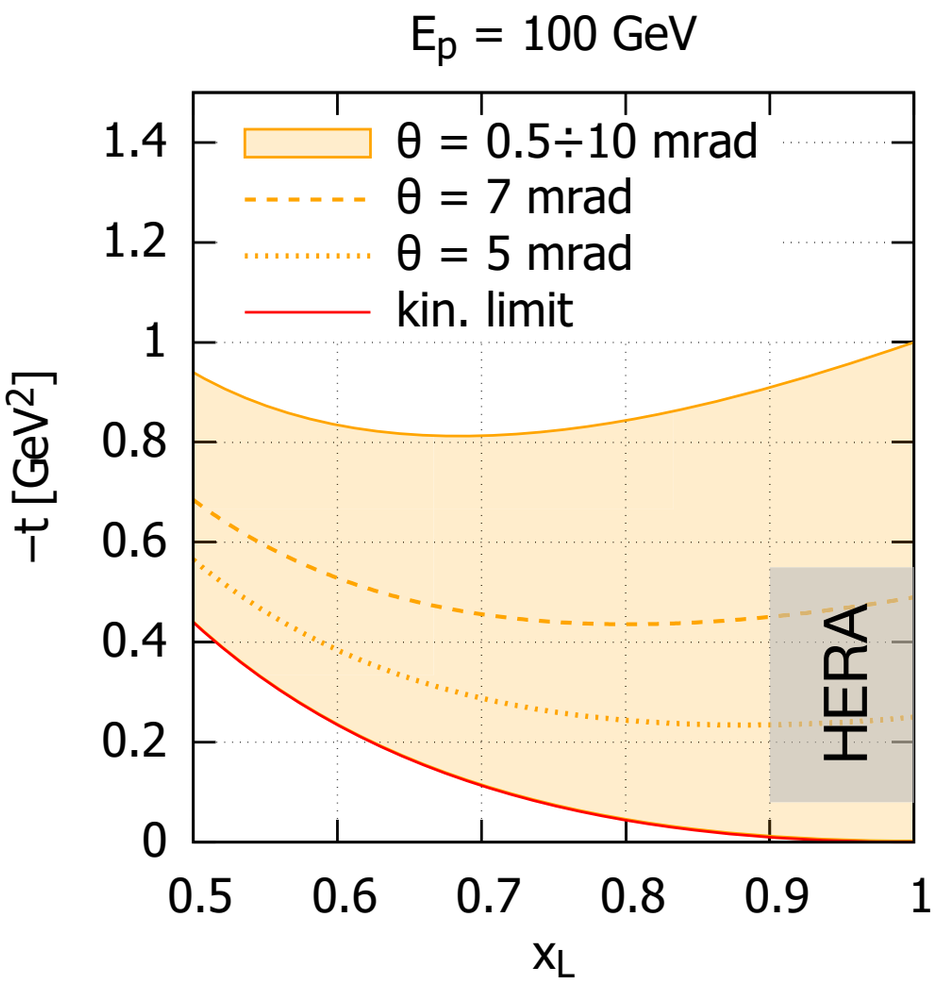

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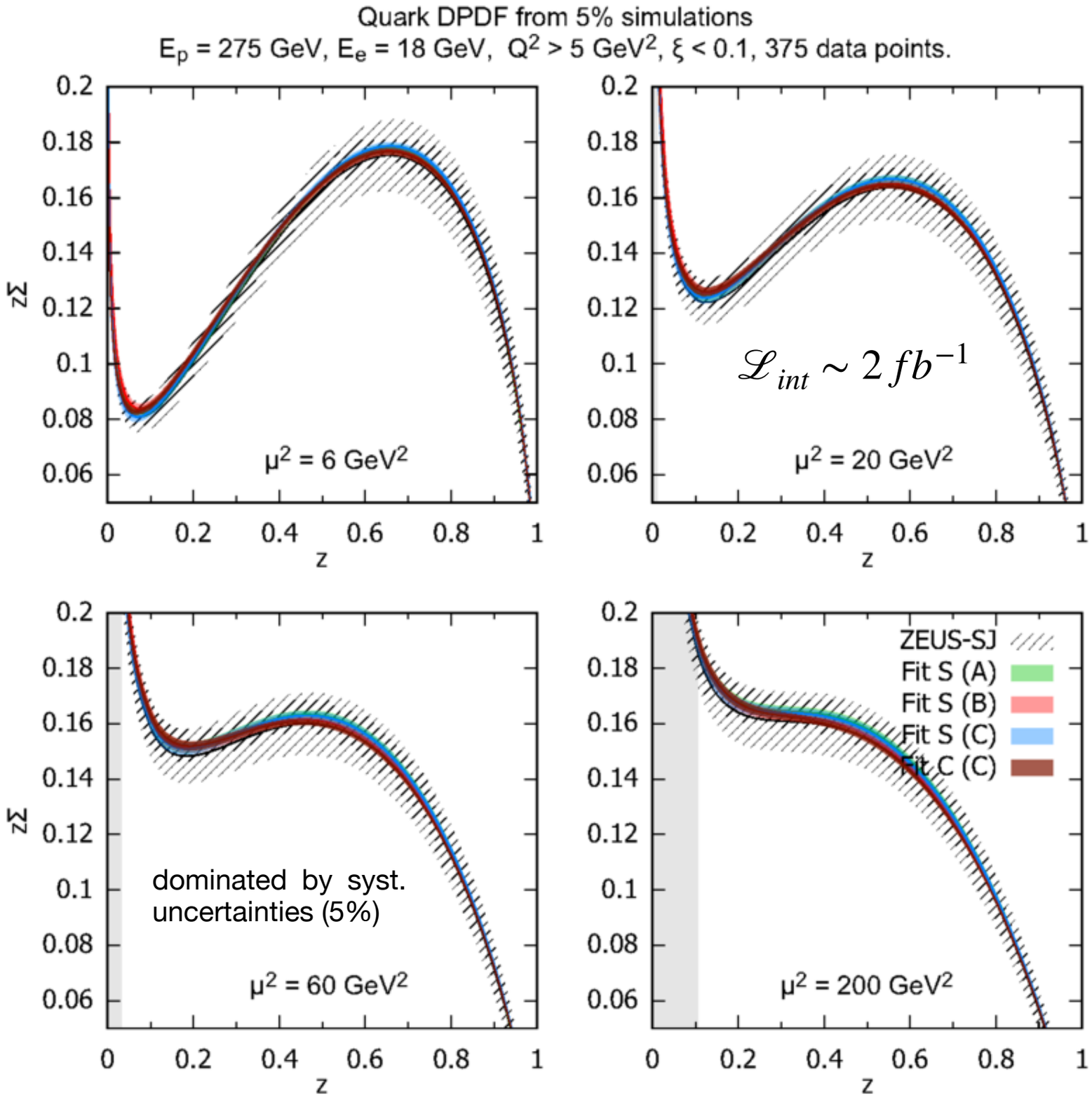
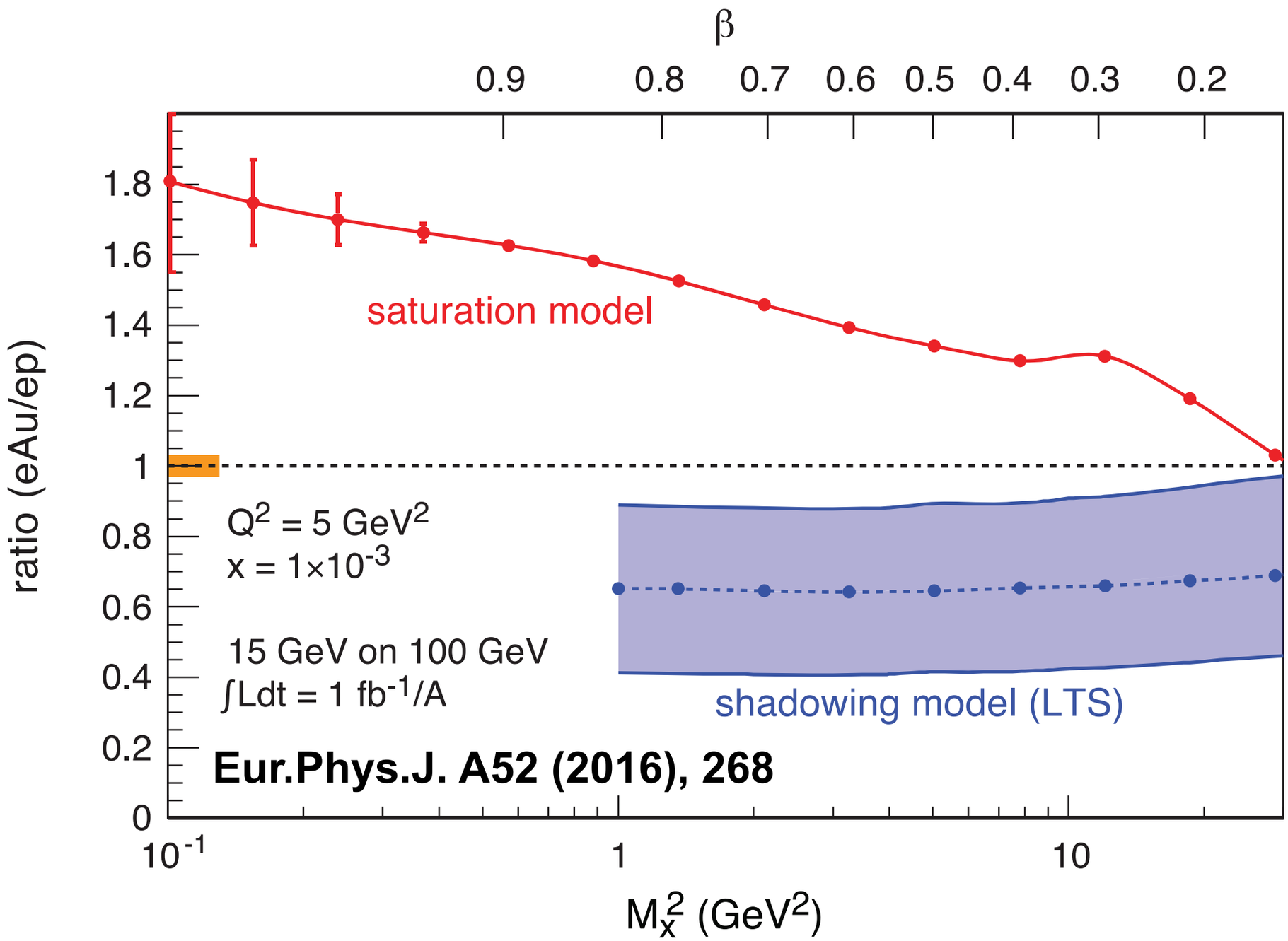


Diffractive cross-sections



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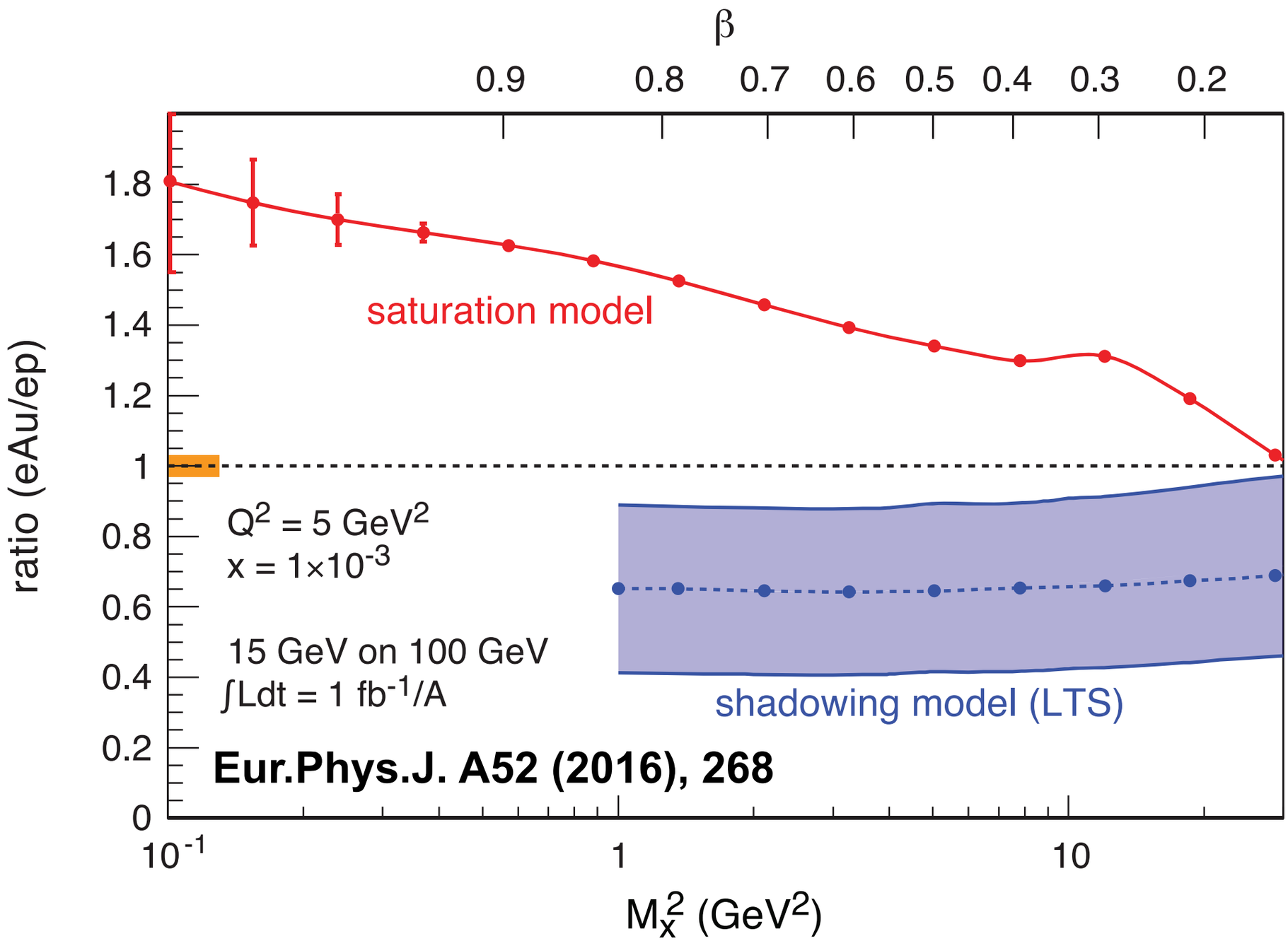


numerator : day 503 measurement (year 2, p)

denominator: day 1096 measurement (years 4 and 5, Au) **NEW!**

Diffractive di-jet photo-production

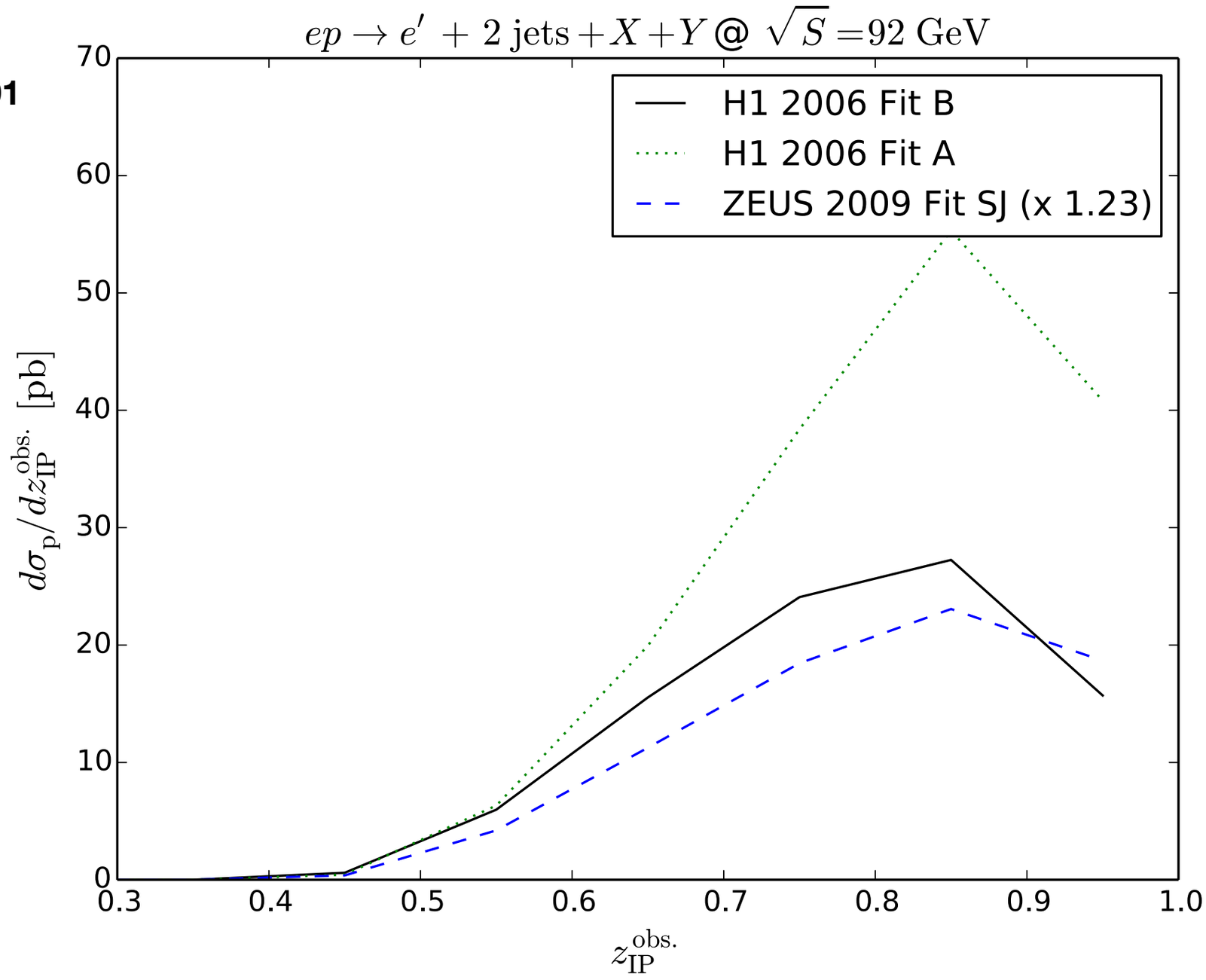
Is factorisation broken?

Z. Phys. C 68 (1995) 113–120

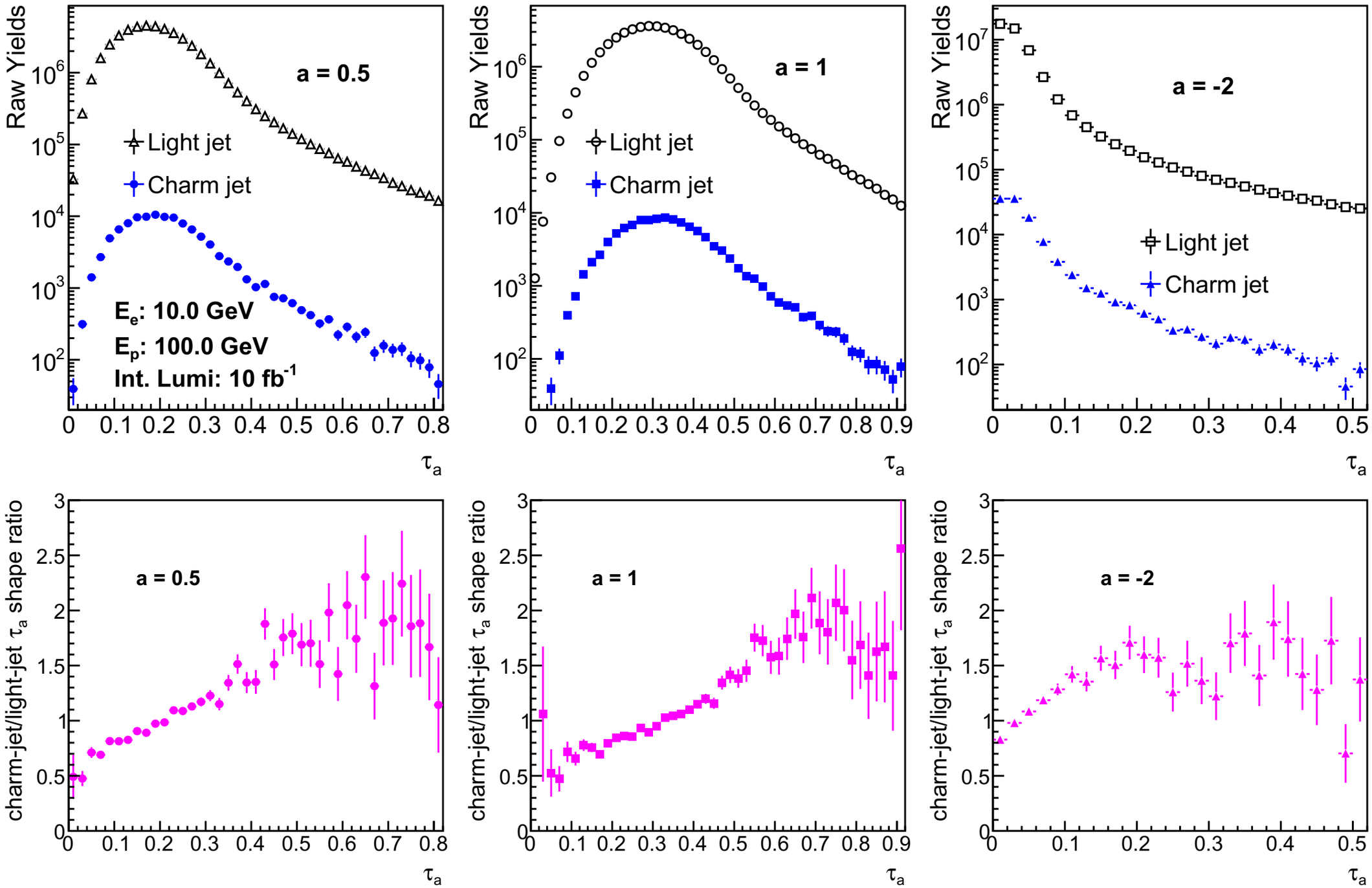
Rept.Prog.Phys. 85 (2022) 12, 126301

JHEP 05 (2020) 074

very sensitive to the DPDFs set used



Tagged Jet angularities in e+p

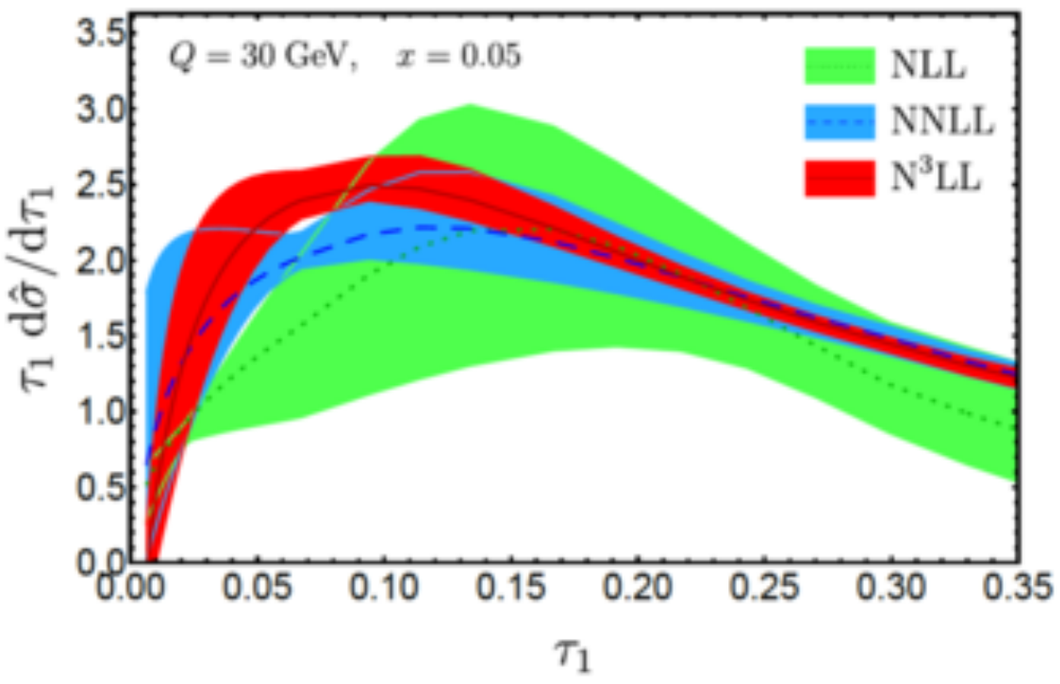


⚔️ All sort of studies of jet substructure

Global event shapes

1-jettiness τ_1^b (τ_1^a)

very sensitive to α_s



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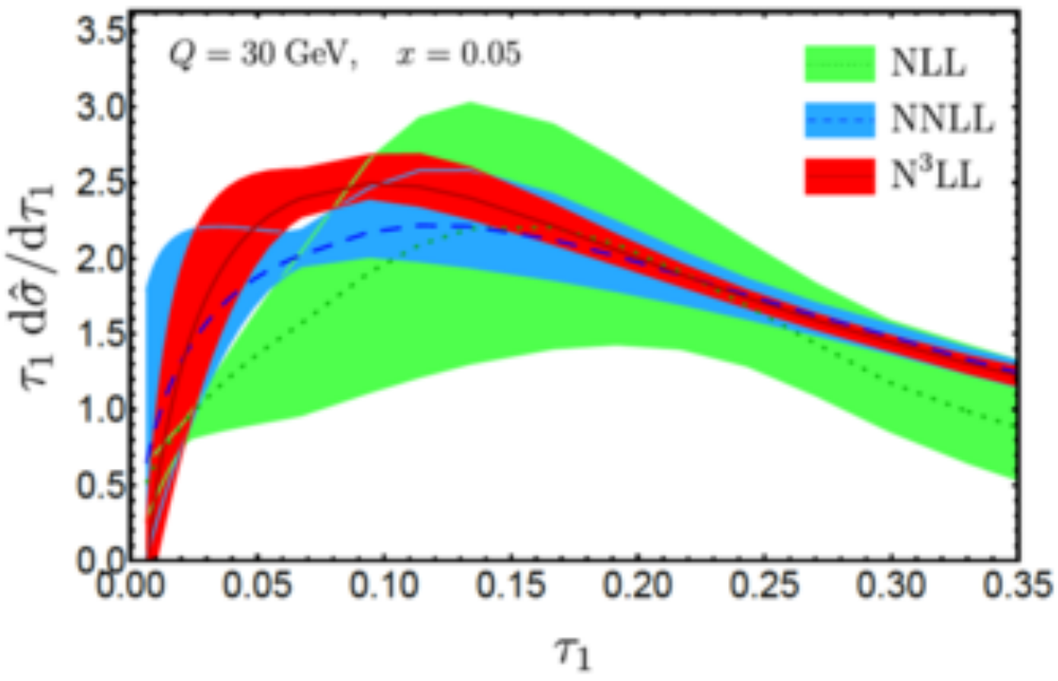
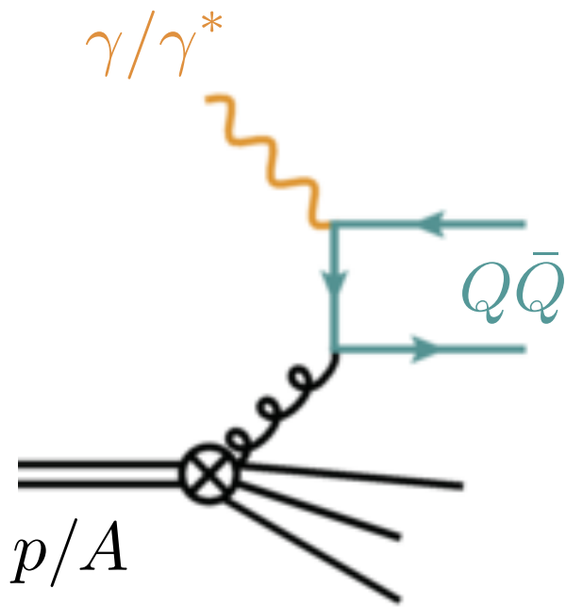
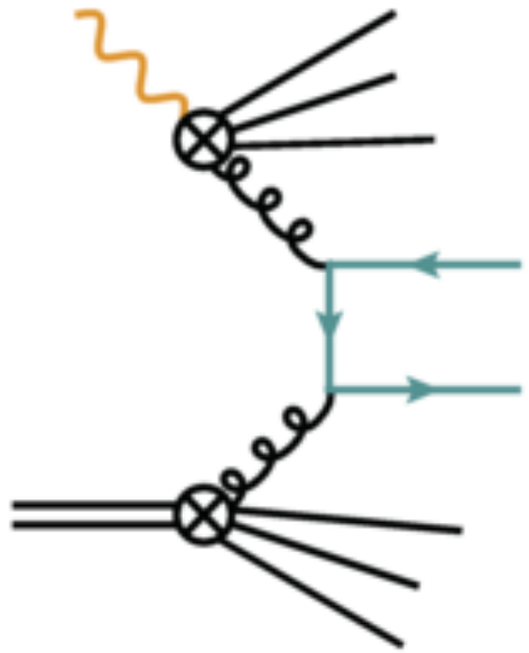


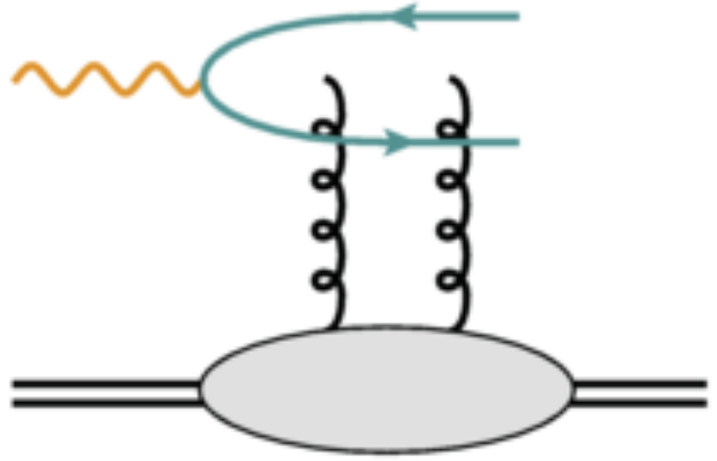
Target fragmentation and fracture functions

⚔ Very limited experimental data

Quarkonia production mechanism







direct lepto/photon | resolved | exclusive/diffractive

⚔️ Three models for the actual production mechanism. Data are inconclusive.

⚔️ EIC can measure all three processes by exploring different kinematic regimes.

Observables we know nothing about

Parity-violating DIS

Unpolarised electrons and polarised hadrons, contribute to $\Delta\Sigma$ and ΔG

Phys.Rev.D 104 (2021) 3, 034028

⚔ *Parity-violating DIS*

Unpolarised electrons and polarised hadrons, contribute to $\Delta\Sigma$ and ΔG

Phys.Rev.D 104 (2021) 3, 034028

⚔ *Kaon form factors and structure functions*

Testing the feasibility at JLAB (proposed)

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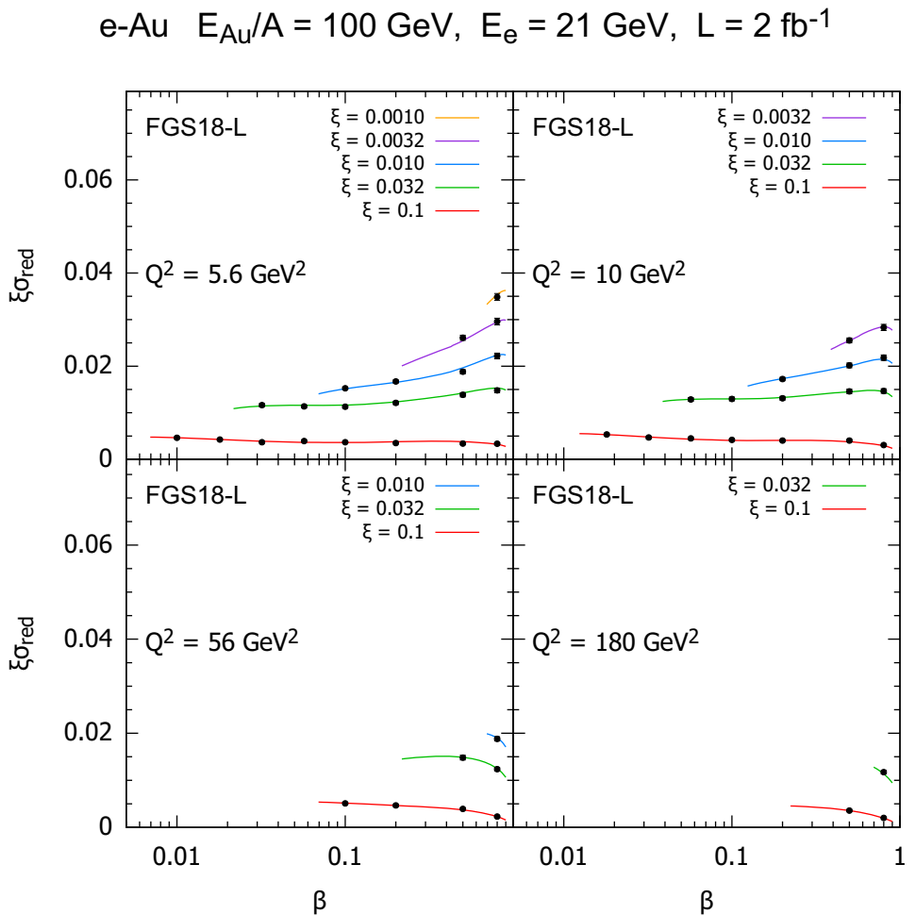

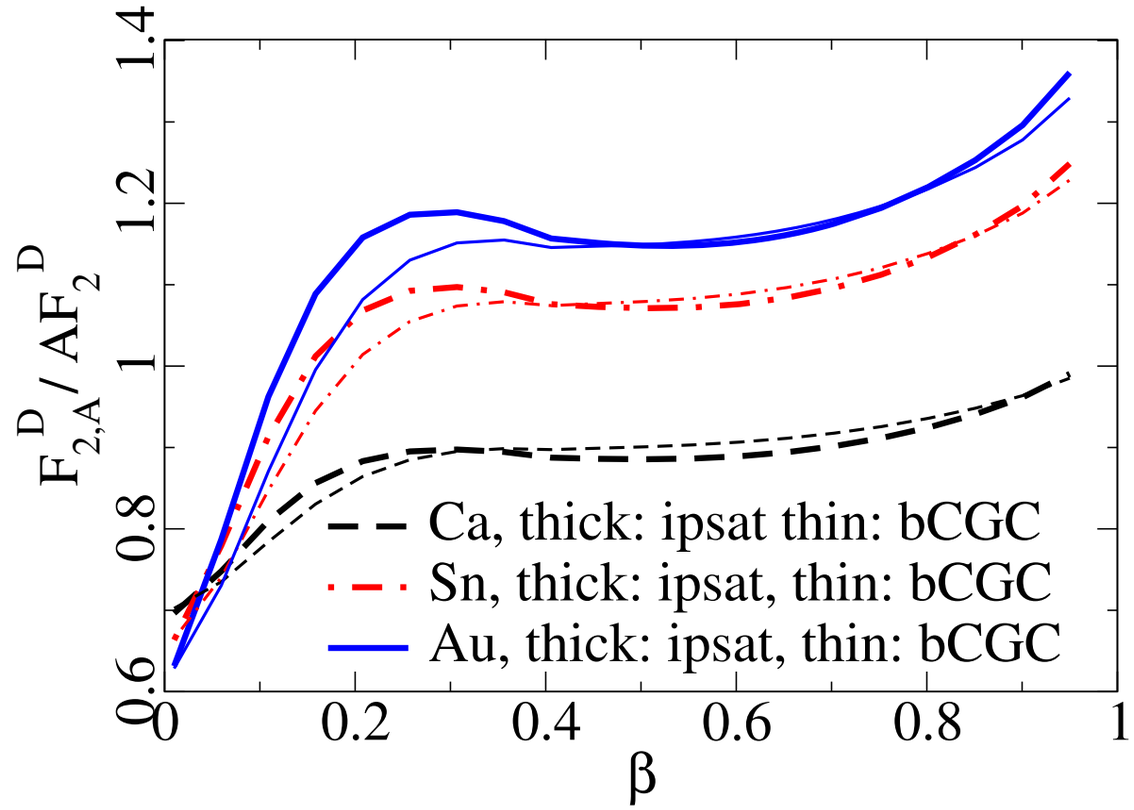

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⚔ *Jets (from any type of process) in e+A*

DIS, diffractive, photo-production, etc. Energy loss, medium properties, saturation. Substructure and flavour tagging.

⚔️ *Parity-violating DIS*

Unpolarised electrons and polarised hadrons, contribute to $\Delta\Sigma$ and ΔG

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⚔️ *Inclusive nuclear diffraction and nDPDFs*

⚔️ *Jets (from any type of process) in e+A*

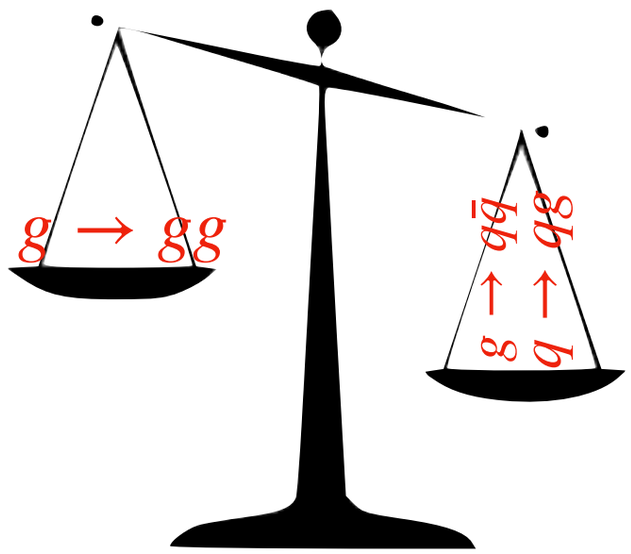
DIS, diffractive, photo-production, etc. Energy loss, medium properties, saturation. Substructure and flavour tagging.

⚔️ *Large |t| diffractive production of vector mesons*

Saturation

DIS is not the most adequate observable (scaling?)

in e+A: coherent, incoherent and dissociative incoherent

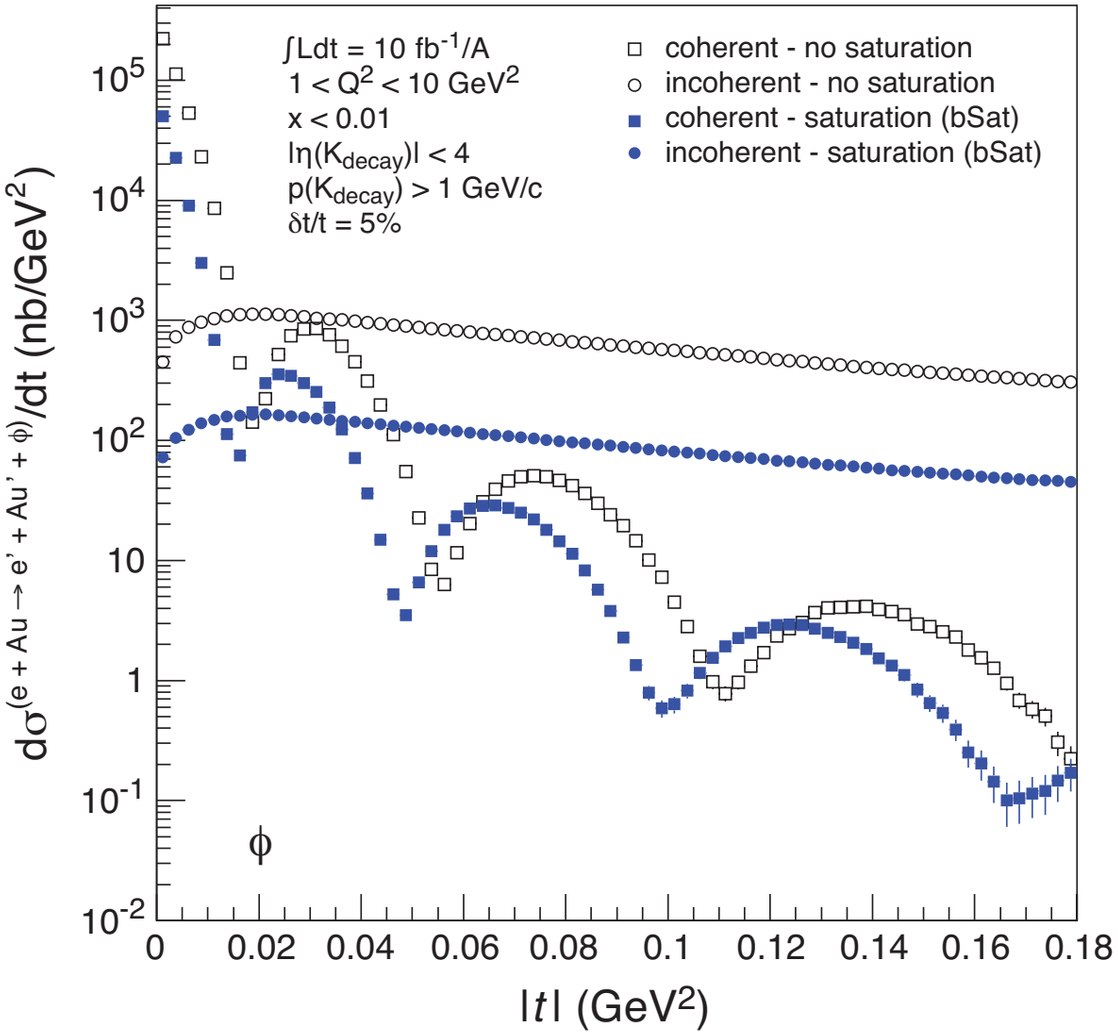


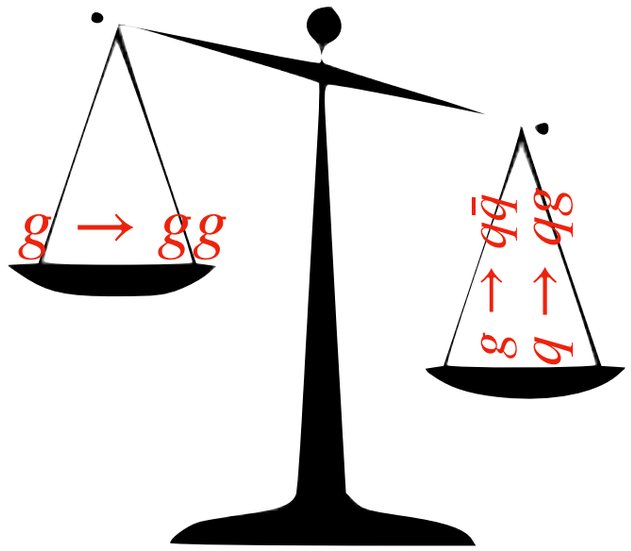
Saturation

DIS is not the most adequate observable

in e+A: coherent, incoherent and dissociative incoherent

exclusive production



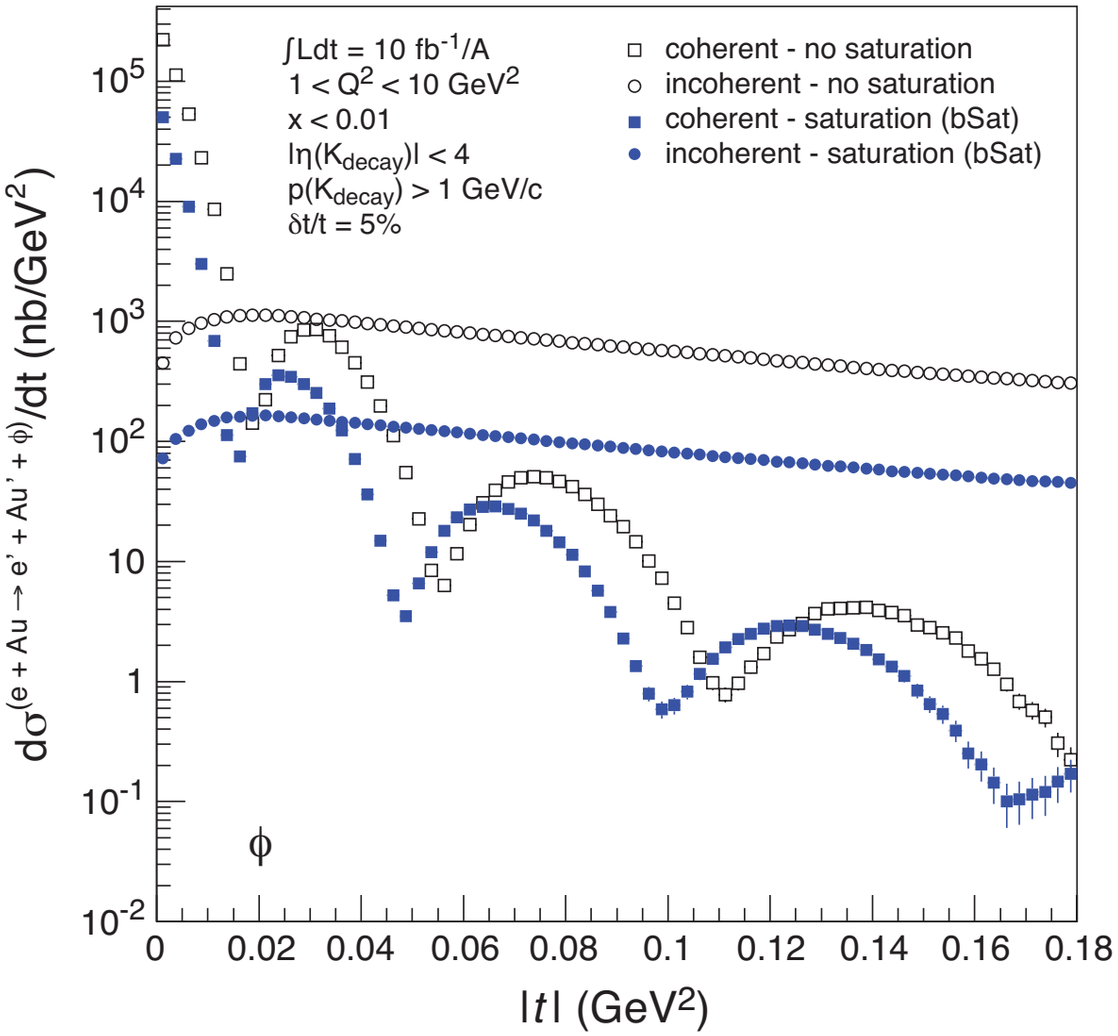


Saturation

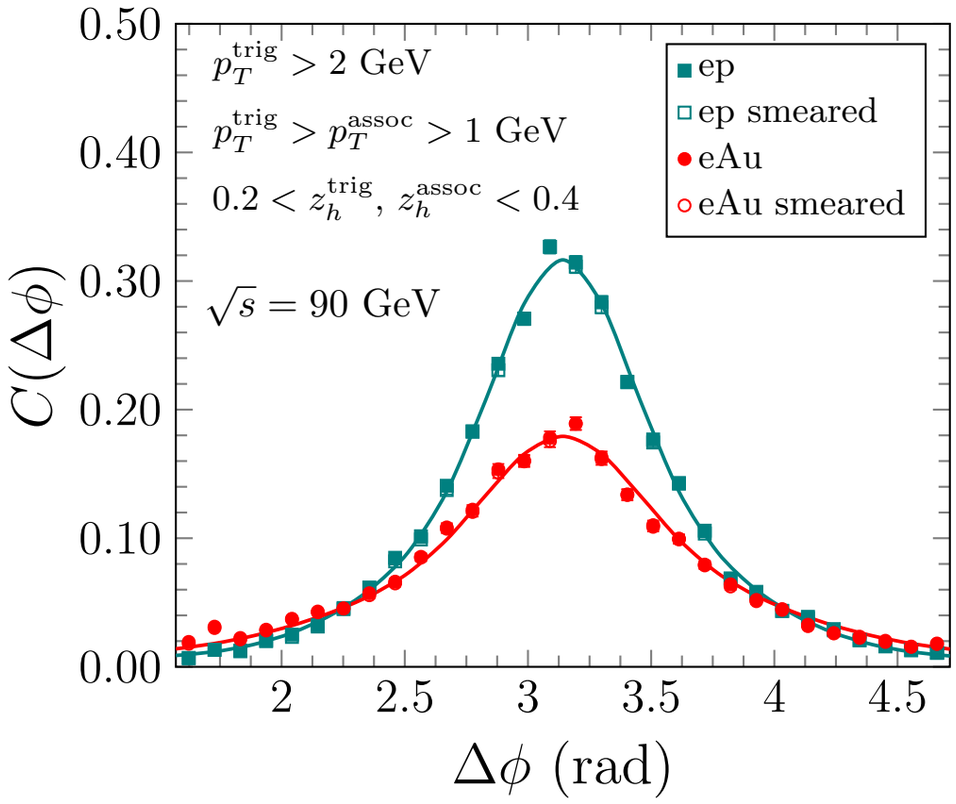
DIS is not the most adequate observable

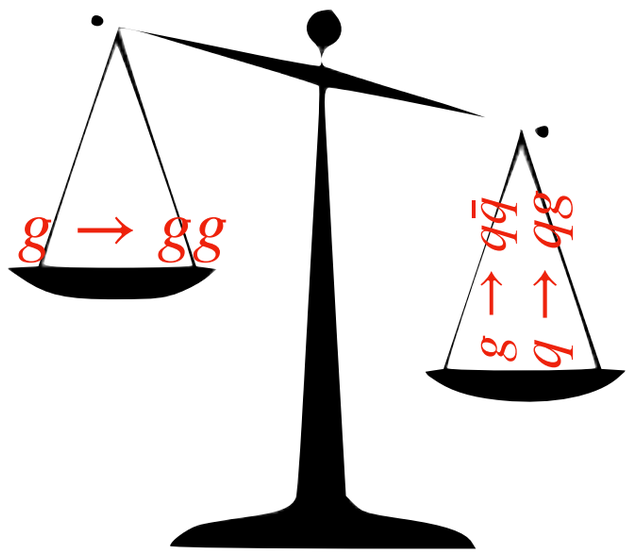
in e+A: coherent, incoherent and dissociative incoherent

exclusive production



di-something azimuthal angle correlations





Summary

⚔️ Despite not having the fully polarised collider nor the integrated luminosity envisioned in the YR, the first years of the EIC are very promising.

⚔️ It will be possible to use early first data to improve on observables that we are familiar with (plus contributions from other experiments before EIC starts).

⚔️ Even without all nuclear species and “low” luminosity, many observables are absolutely new and exciting.

⚔️ Careful and realistic studies are the next step.

⚔️ I would not rule out anything that is not 100% impossible for now.

⚔️ Ru vs. Cu? Choose Ru!

We have come a long way from the YR, but we have a lot more to do.

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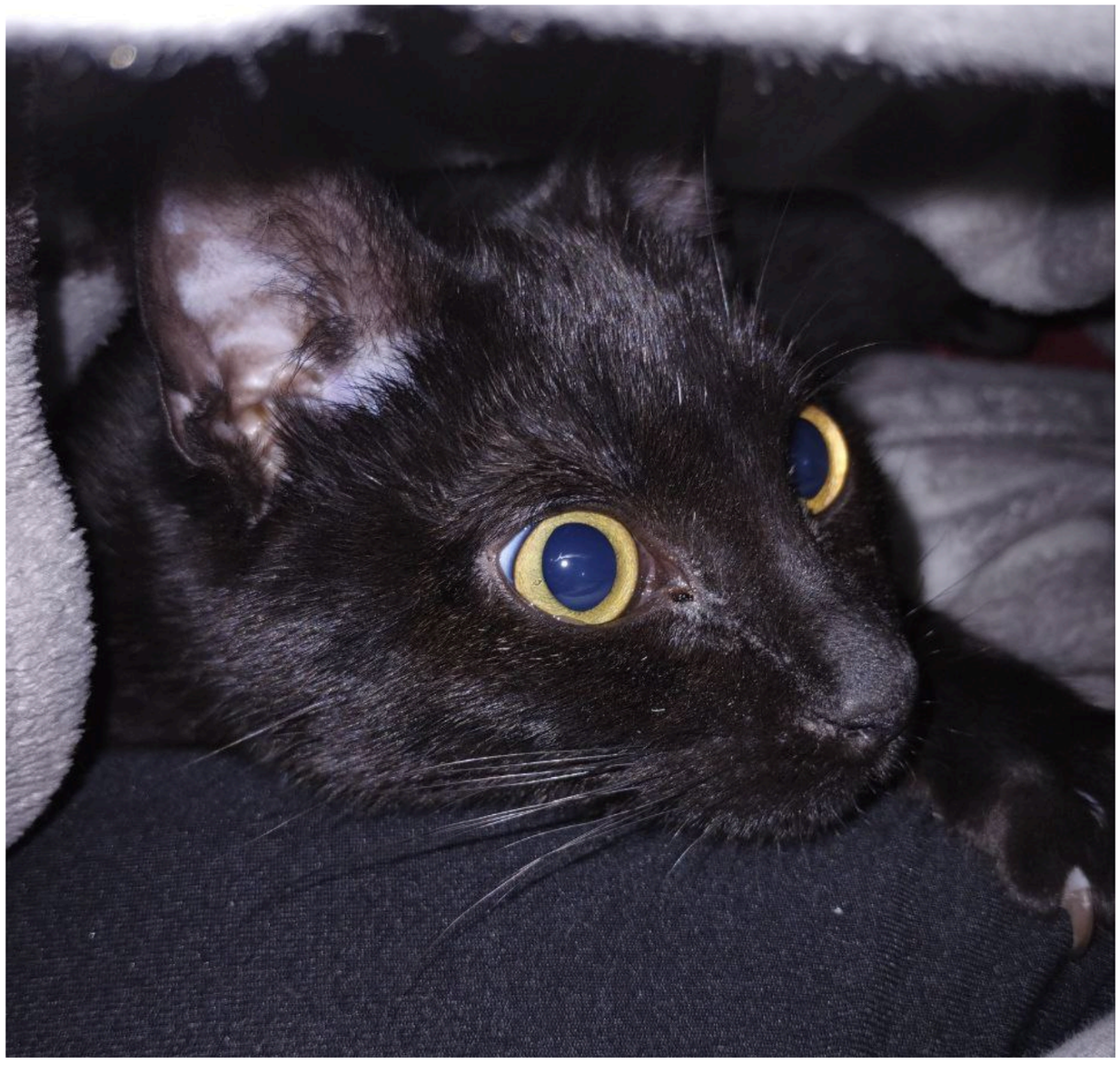
We just need to keep studying QCD. After all, curiosity didn't kill the cat…

… it just landed him at the vet a couple of times.



Thank you for your attention!