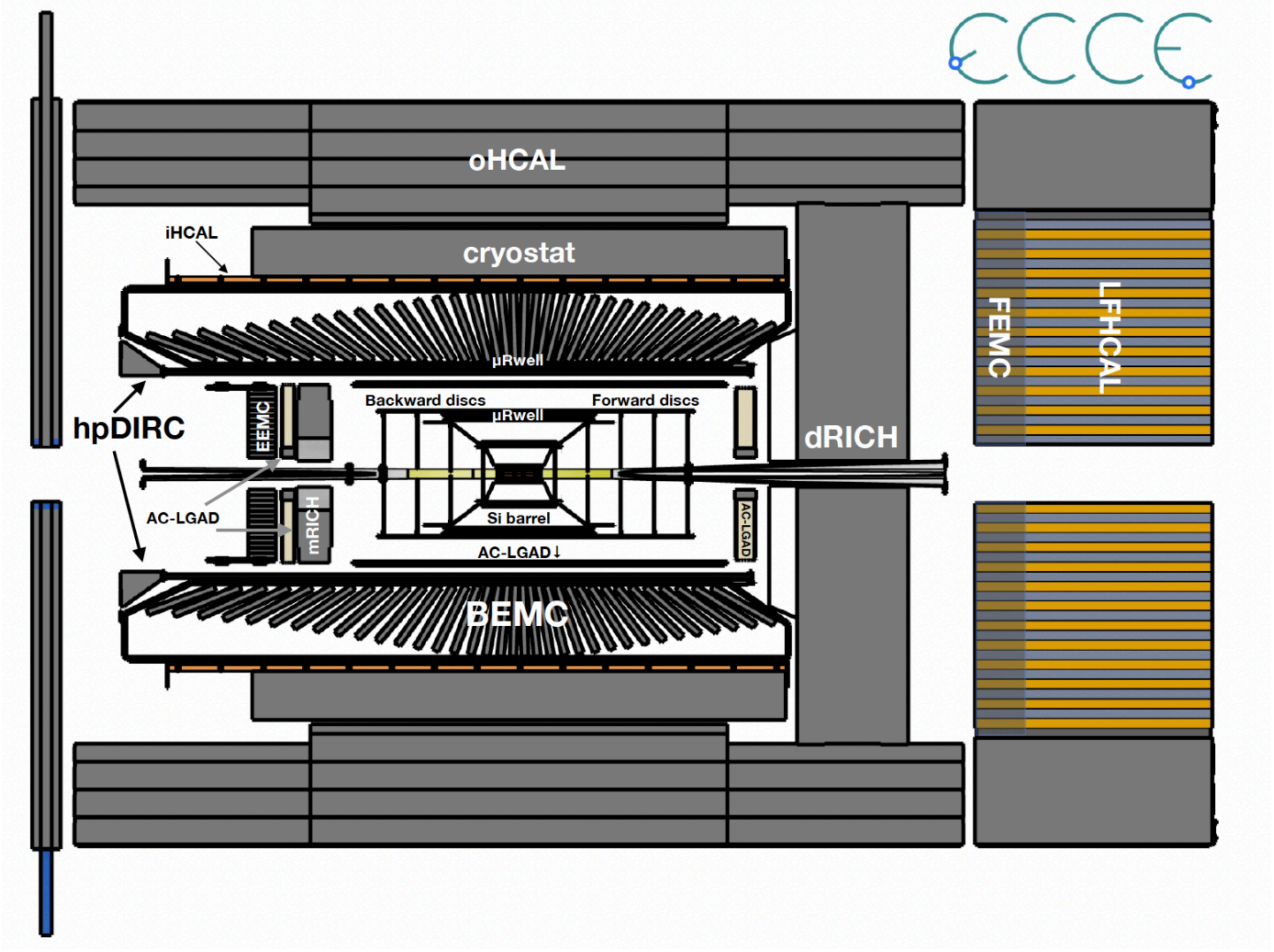
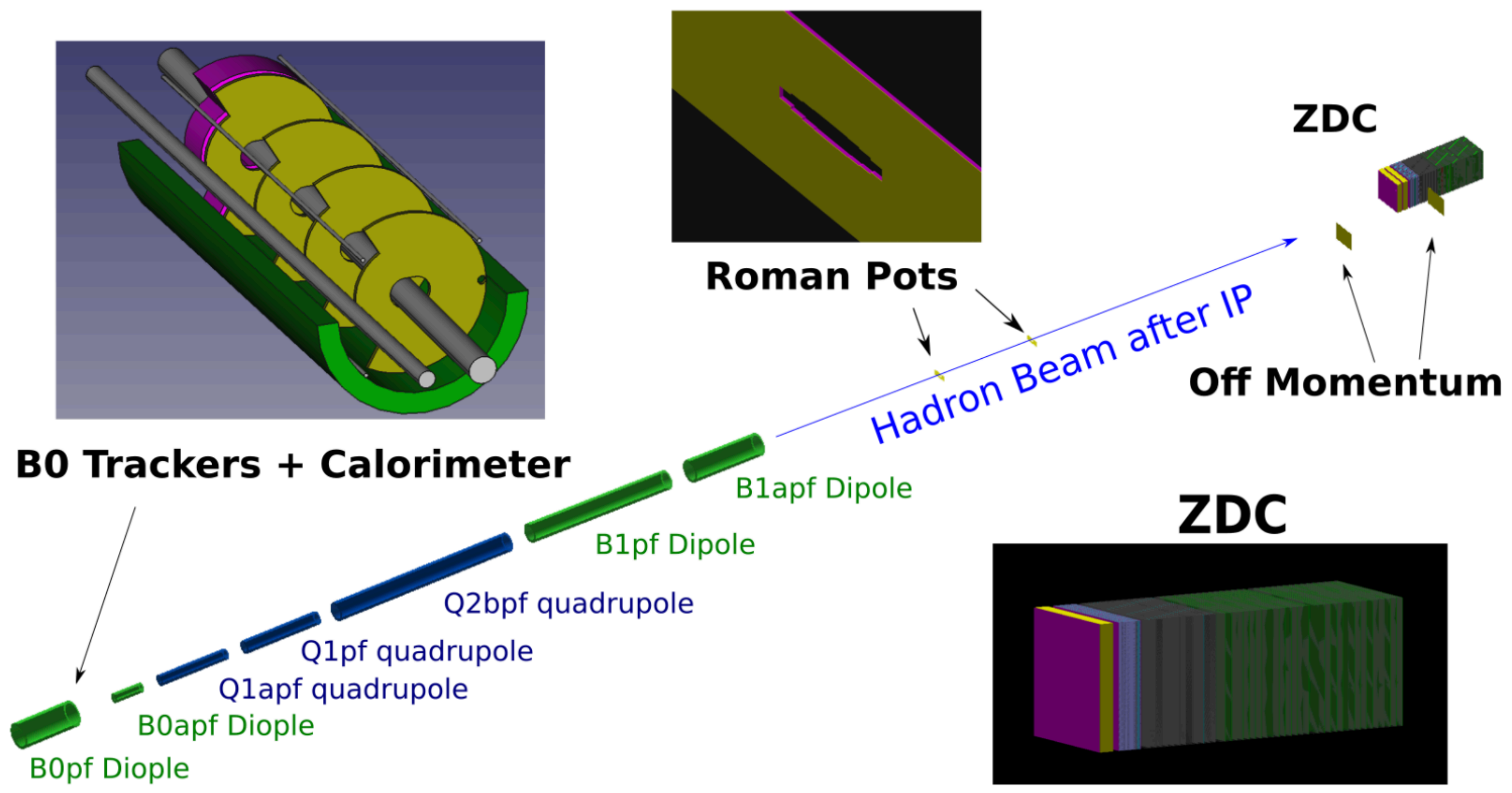
Current analysis on extracting α_s from Spin Structure functions at ePIC

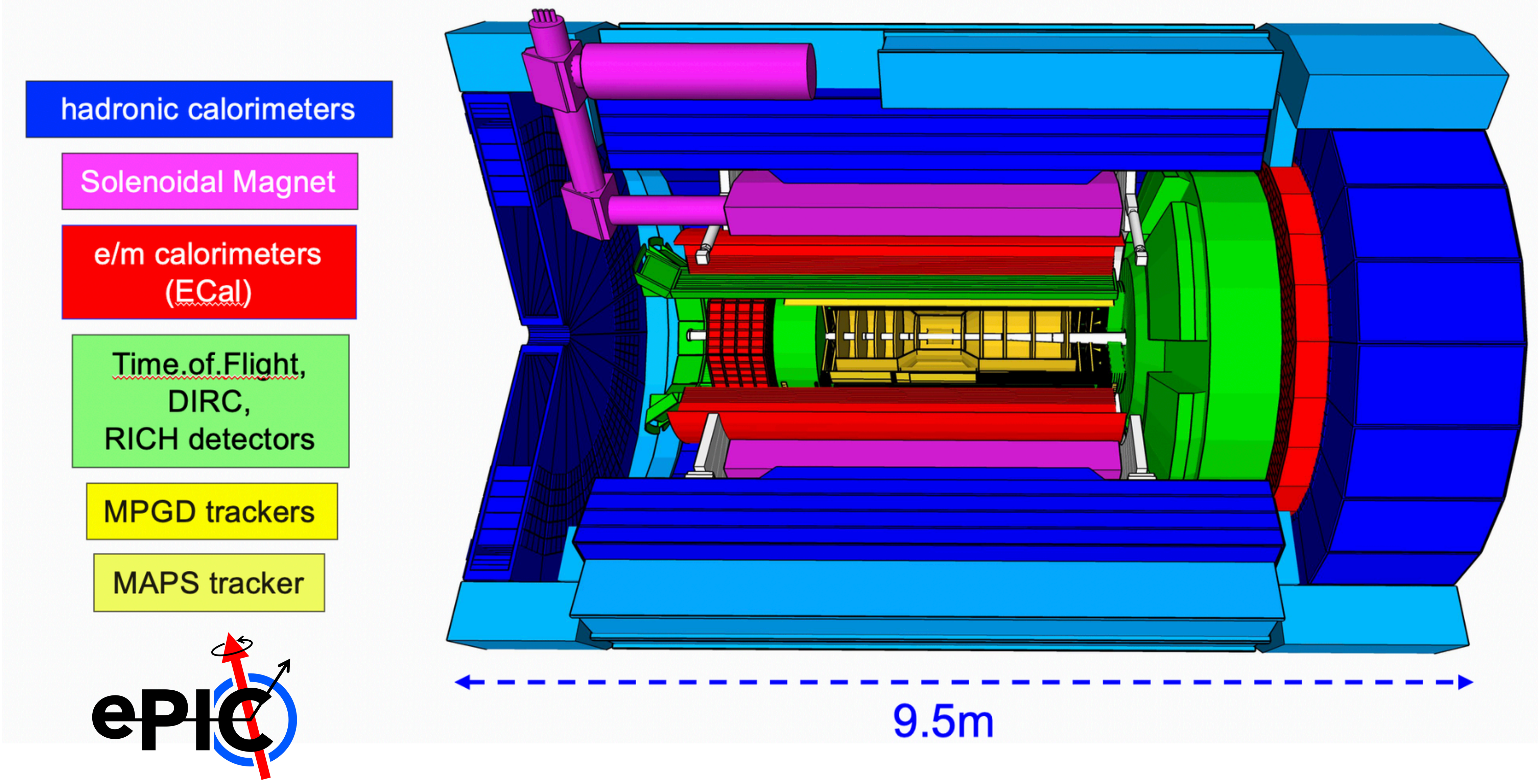
Win Lin
Stony Brook University

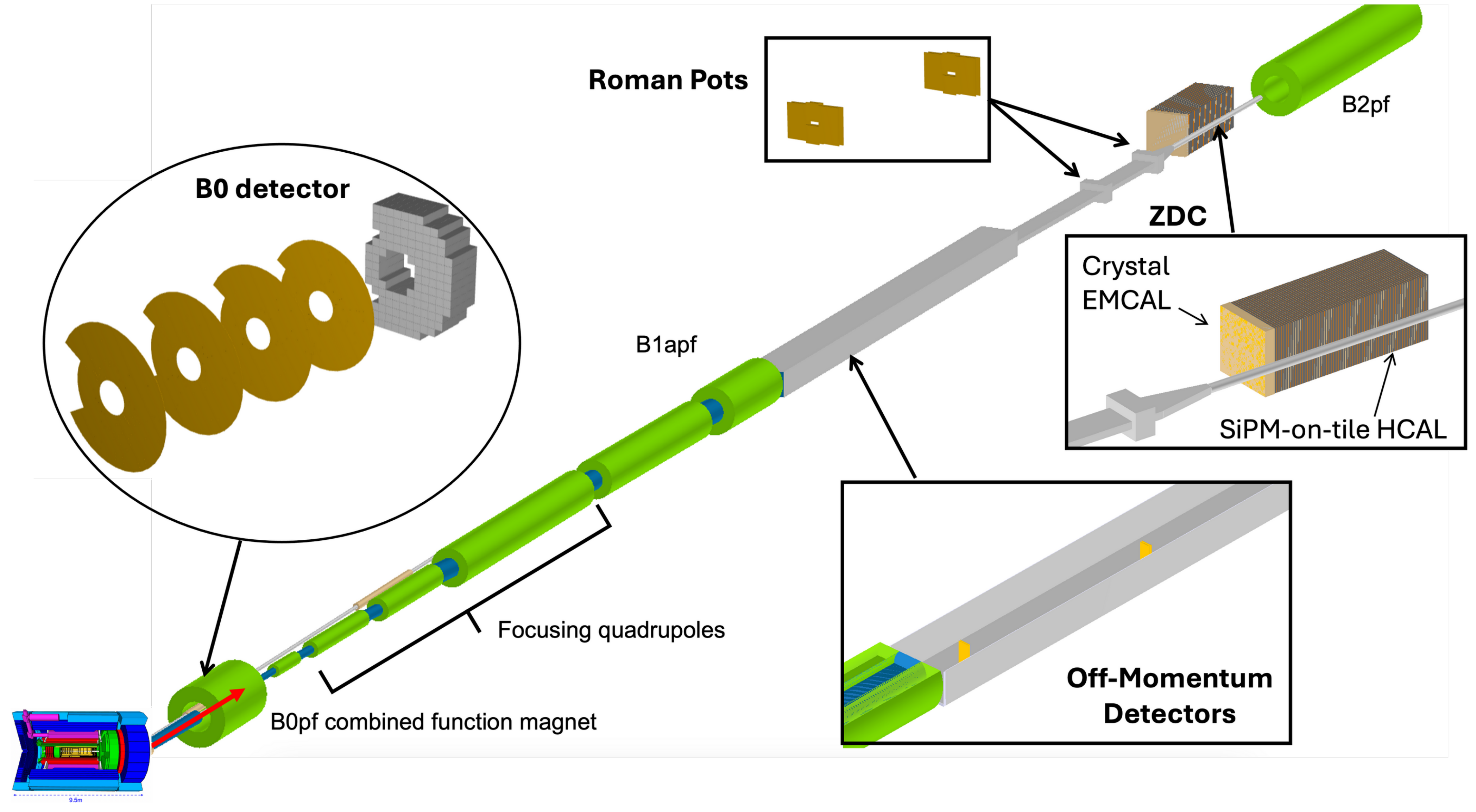
Extracting the Strong Coupling at the EIC and other Future Colliders
05/03/2025

Analysis with updated detector design









Analysis with different event generators

New analysis:

BeAGLE → eic-smear → Afterburner → epic simulation → EICrecon → Analysis

Pythia 8

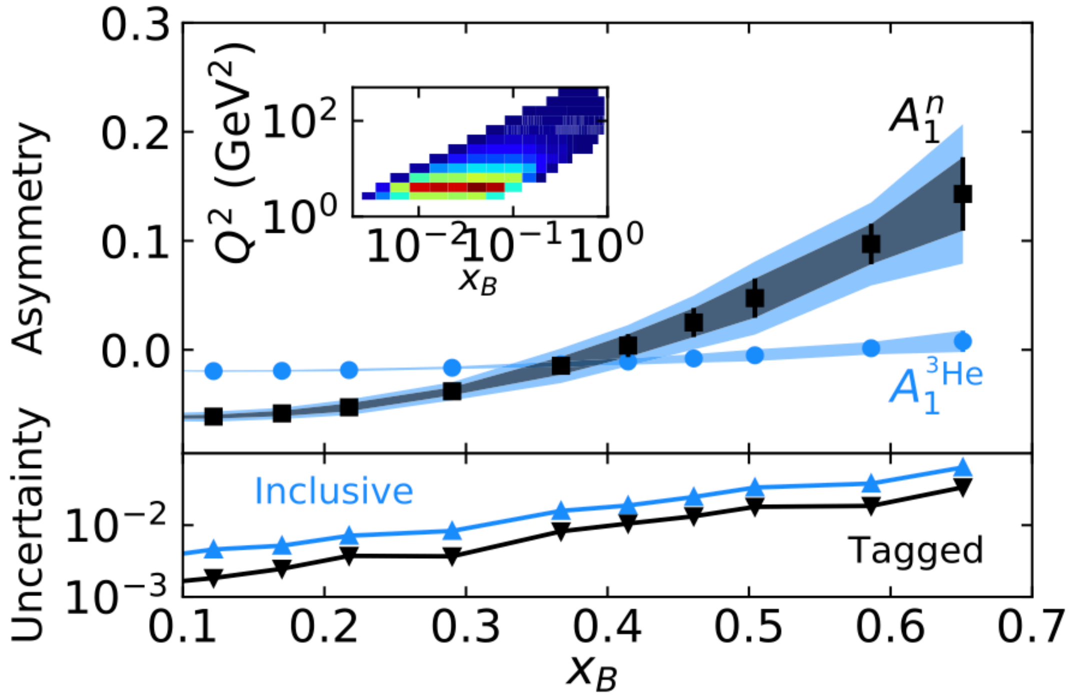
- *ep* DIS with radiative effect
- Not polarized

BeAGLE

- *eA* DIS
- Not polarized
- No radiative effect

CLASDIS

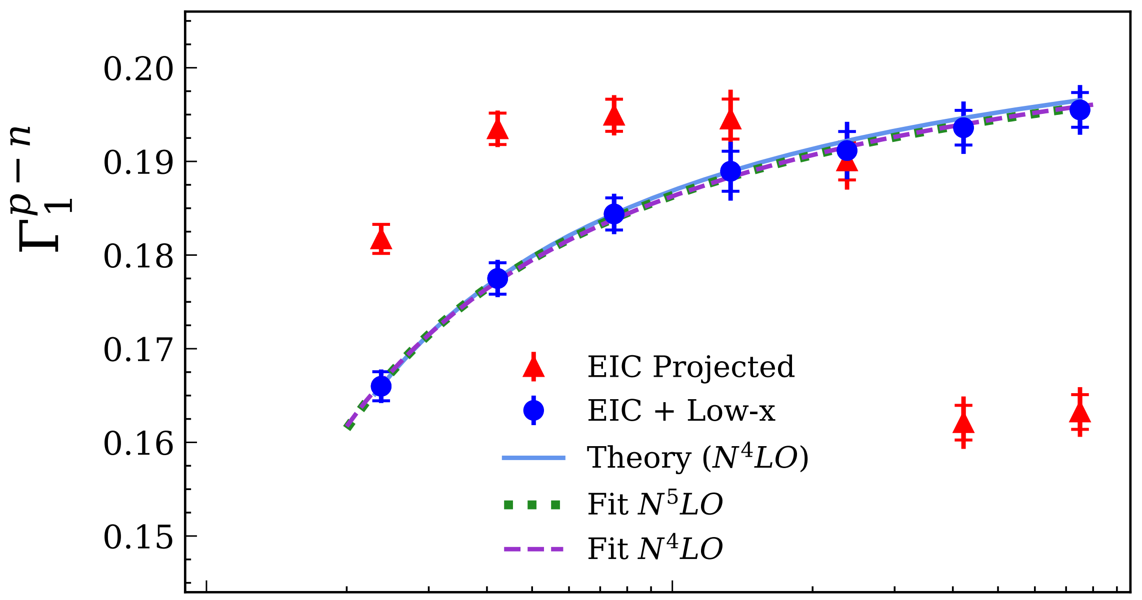
- *ep* polarized DIS for fixed target experiment
- Spectators were generate separately then re-weighted for nuclear effect
- Used DJANGOH for radiative effect



https://doi.org/10.1103/PhysRevD.110.074004

DJANGOH

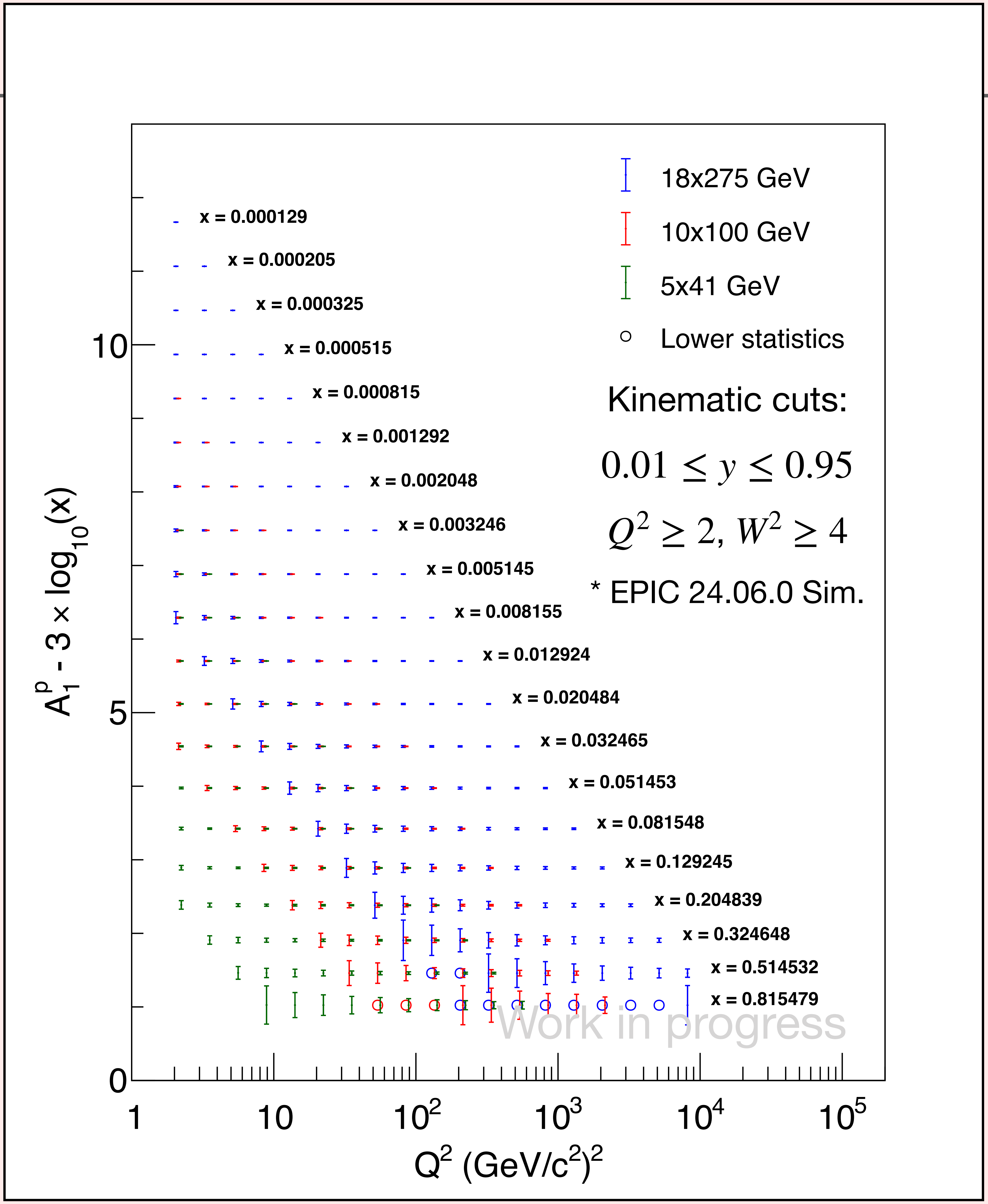
- *ep* polarized DIS with QED and QCD radiative effect
- For e^3He, spectators were also generated separately

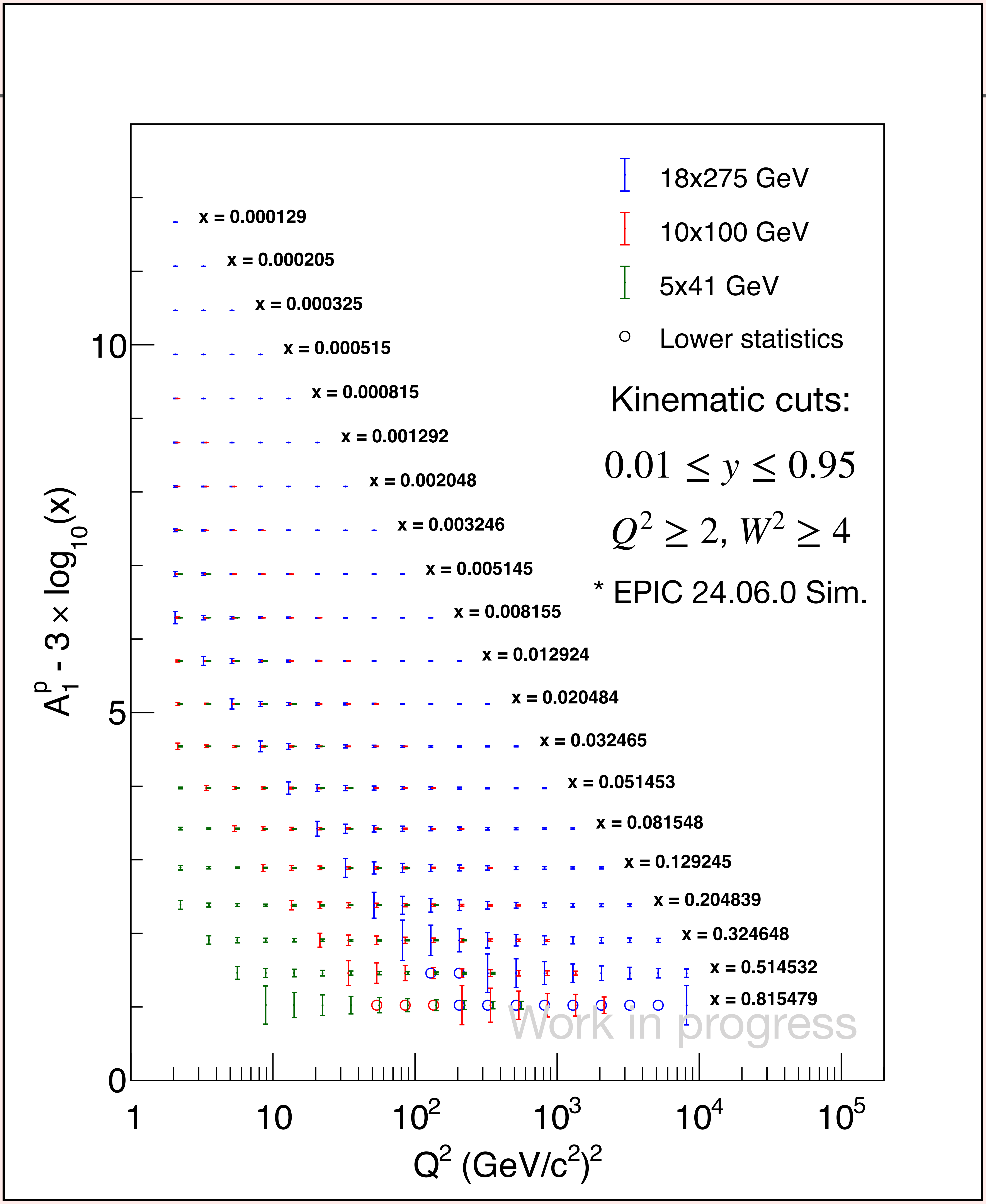


https://doi.org/10.1016/j.physletb.2021.136726

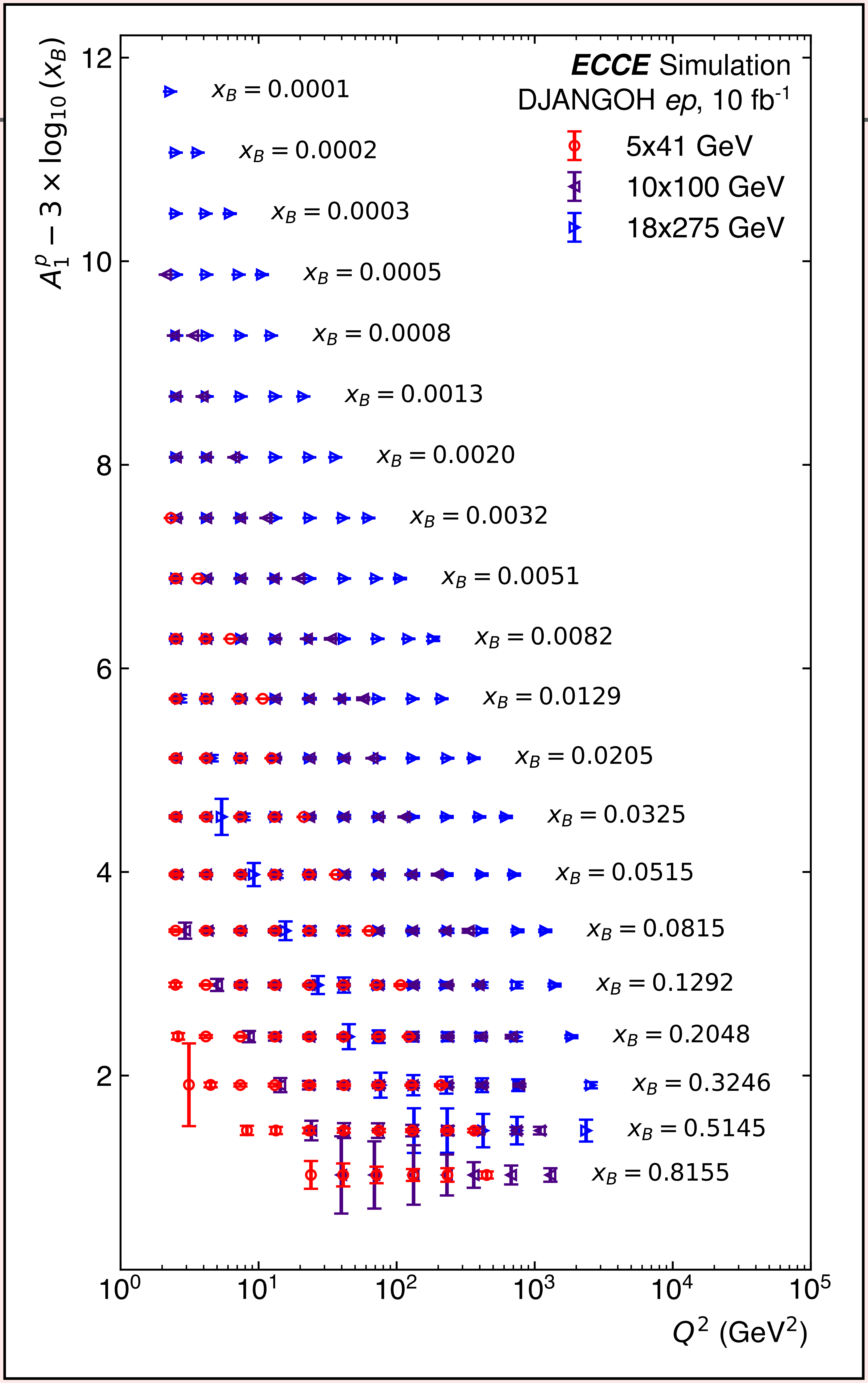
A_1^p from ep DIS:

- $A_1(x, Q^2) \equiv \dfrac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \dfrac{A_\parallel}{D(1+\eta\xi)} - \dfrac{\eta A_\perp}{d(1+\eta\xi)}$
- $\mathscr{L} = 10\ \text{fb}^{-1}$, $P_e = P_n = 70\,\%$
- Data split evenly between $A_\parallel$ and $A_\perp$
- $\delta A_{\parallel,\perp} = \dfrac{1}{\sqrt{N} P_e P_N}$
- Bin A_1^n calculated from: Doi: 10.2172/824895
- Statistical uncertainty only, correction not yet applied

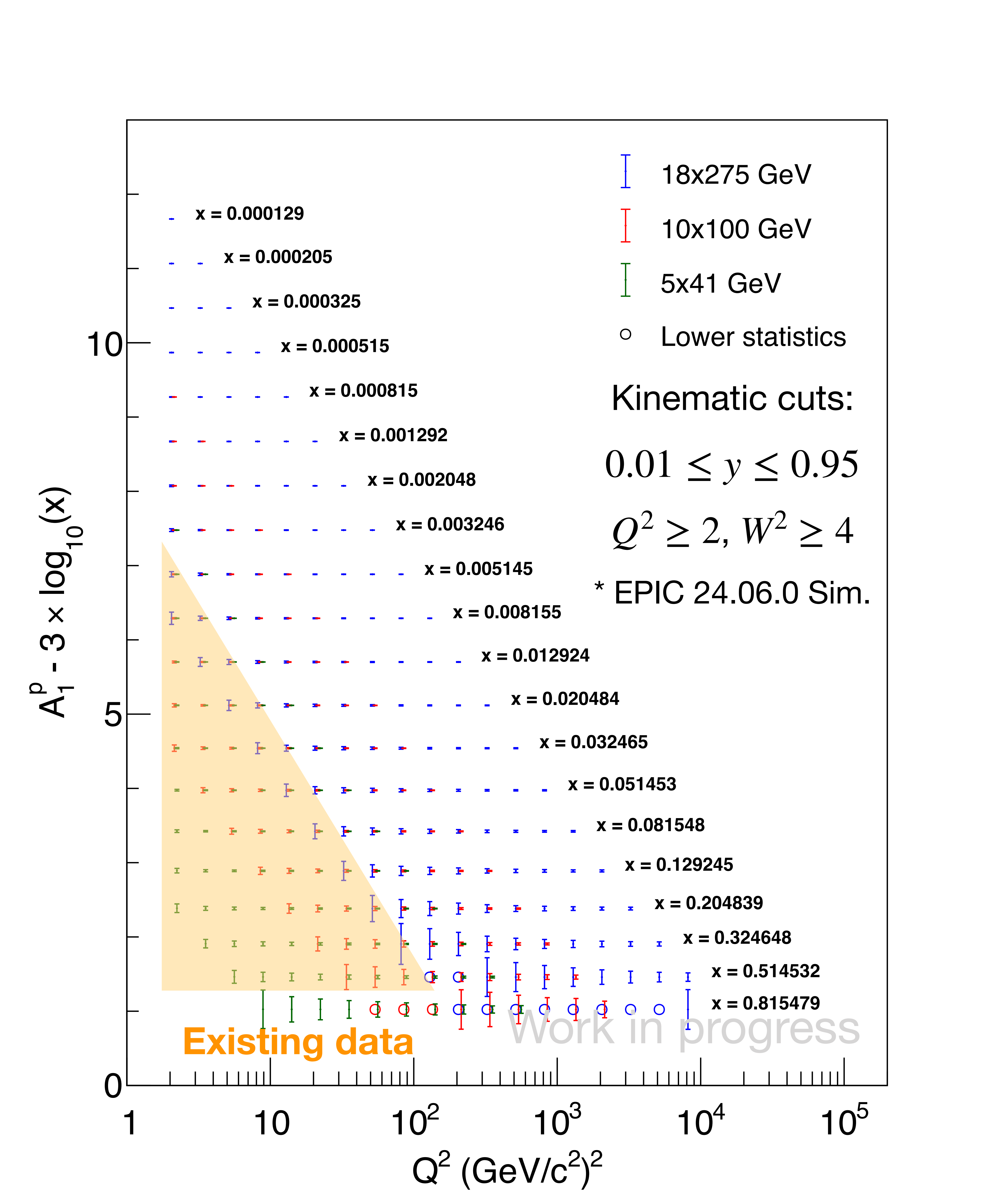




18x275 GeV
10x100 GeV
5x41 GeV
Lower statistics
Kinematic cuts:
$0.01 \leq y \leq 0.95$
$Q^2 \geq 2, W^2 \geq 4$
* EPIC 24.06.0 Sim.
x = 0.000129
x = 0.000205
x = 0.000325
x = 0.000515
x = 0.000815
x = 0.001292
x = 0.002048
x = 0.003246
x = 0.005145
x = 0.008155
x = 0.012924
x = 0.020484
x = 0.032465
x = 0.051453
x = 0.081548
x = 0.129245
x = 0.204839
x = 0.324648
x = 0.514532
x = 0.815479
Work in progress
$A_1^p - 3 \times \log_{10}(x)$
Q^2 (GeV/c^2)^2



ECCE Simulation
DJANGOH ep, 10 fb^{-1}
5x41 GeV
10x100 GeV
18x275 GeV
$x_B = 0.0001$
$x_B = 0.0002$
$x_B = 0.0003$
$x_B = 0.0005$
$x_B = 0.0008$
$x_B = 0.0013$
$x_B = 0.0020$
$x_B = 0.0032$
$x_B = 0.0051$
$x_B = 0.0082$
$x_B = 0.0129$
$x_B = 0.0205$
$x_B = 0.0325$
$x_B = 0.0515$
$x_B = 0.0815$
$x_B = 0.1292$
$x_B = 0.2048$
$x_B = 0.3246$
$x_B = 0.5145$
$x_B = 0.8155$
$A_1^p - 3 \times \log_{10}(x_B)$
Q^2 (GeV^2)



18x275 GeV
10x100 GeV
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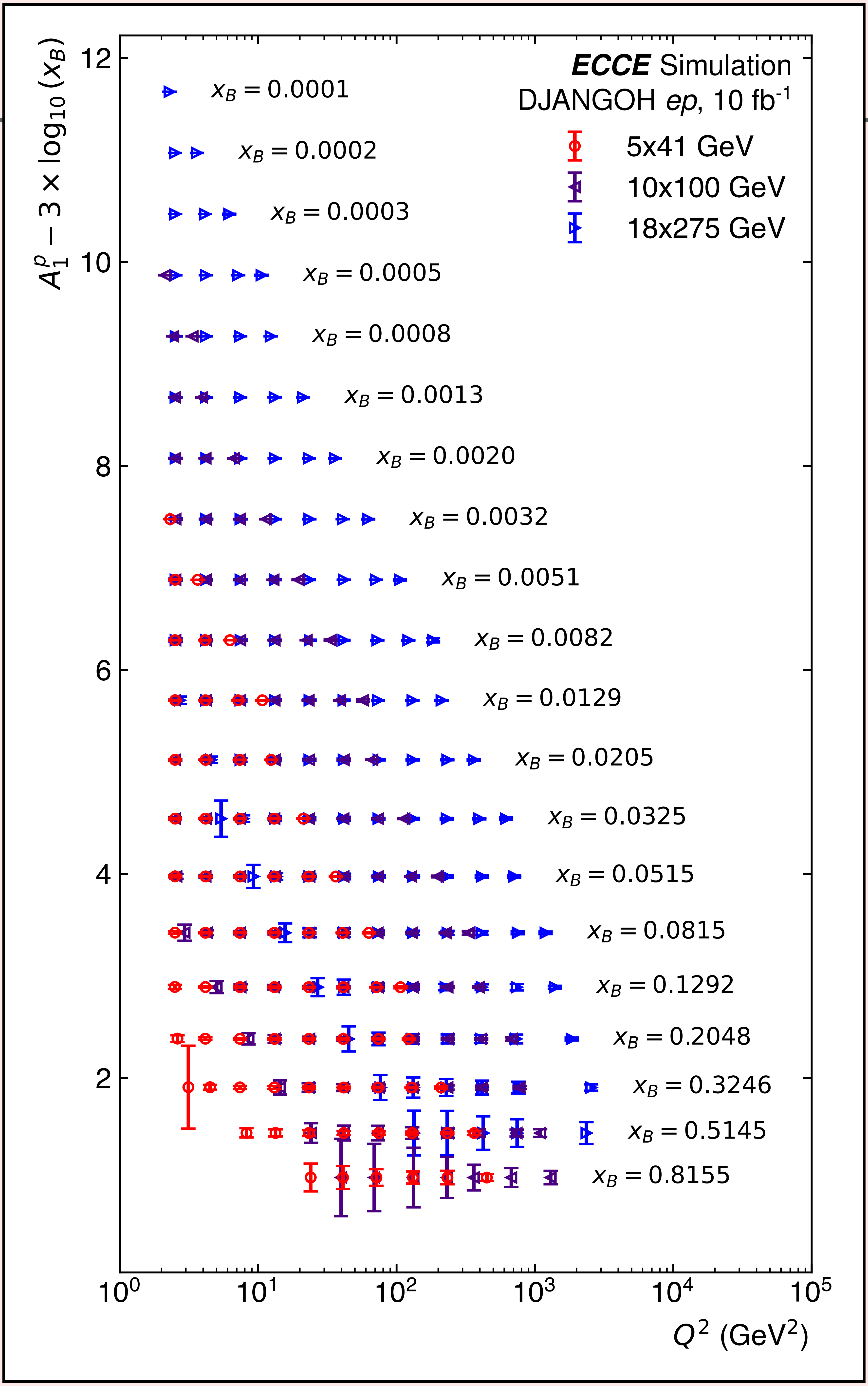
x = 0.051453
x = 0.081548
x = 0.129245
x = 0.204839
x = 0.324648
x = 0.514532
x = 0.815479
Existing data
Work in progress
$A_1^p - 3 \times \log_{10}(x)$
Q^2 (GeV/c^2)^2



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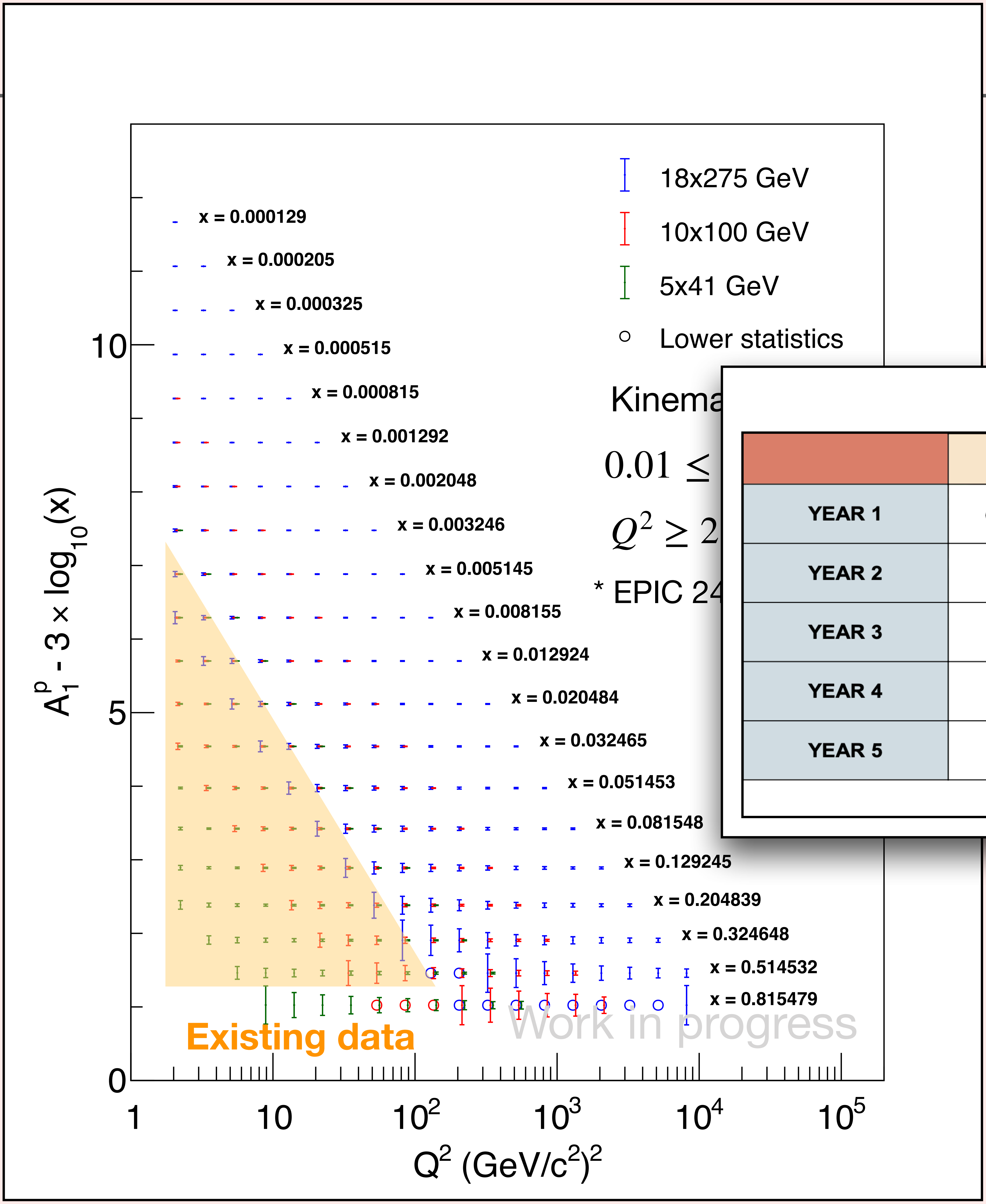
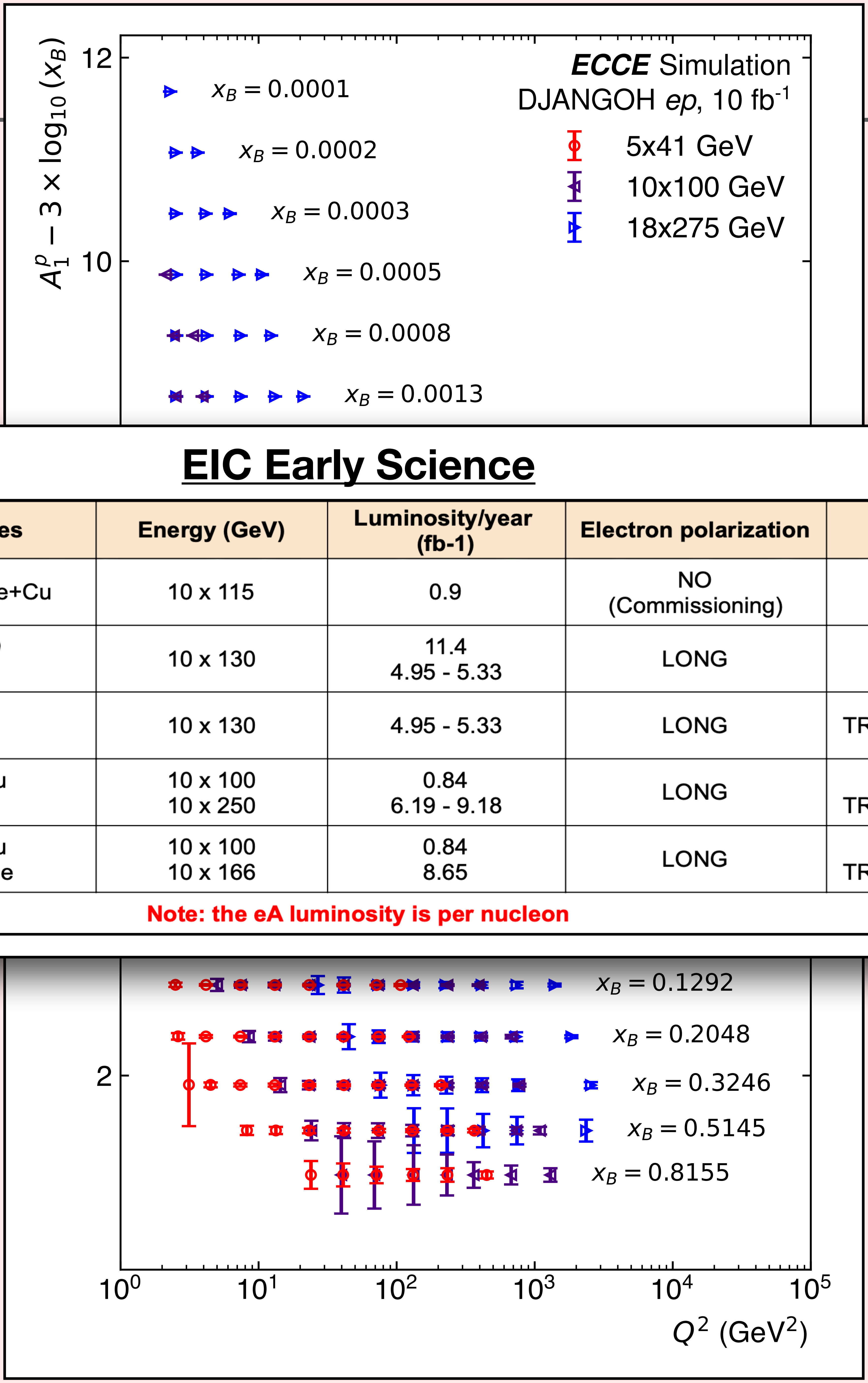




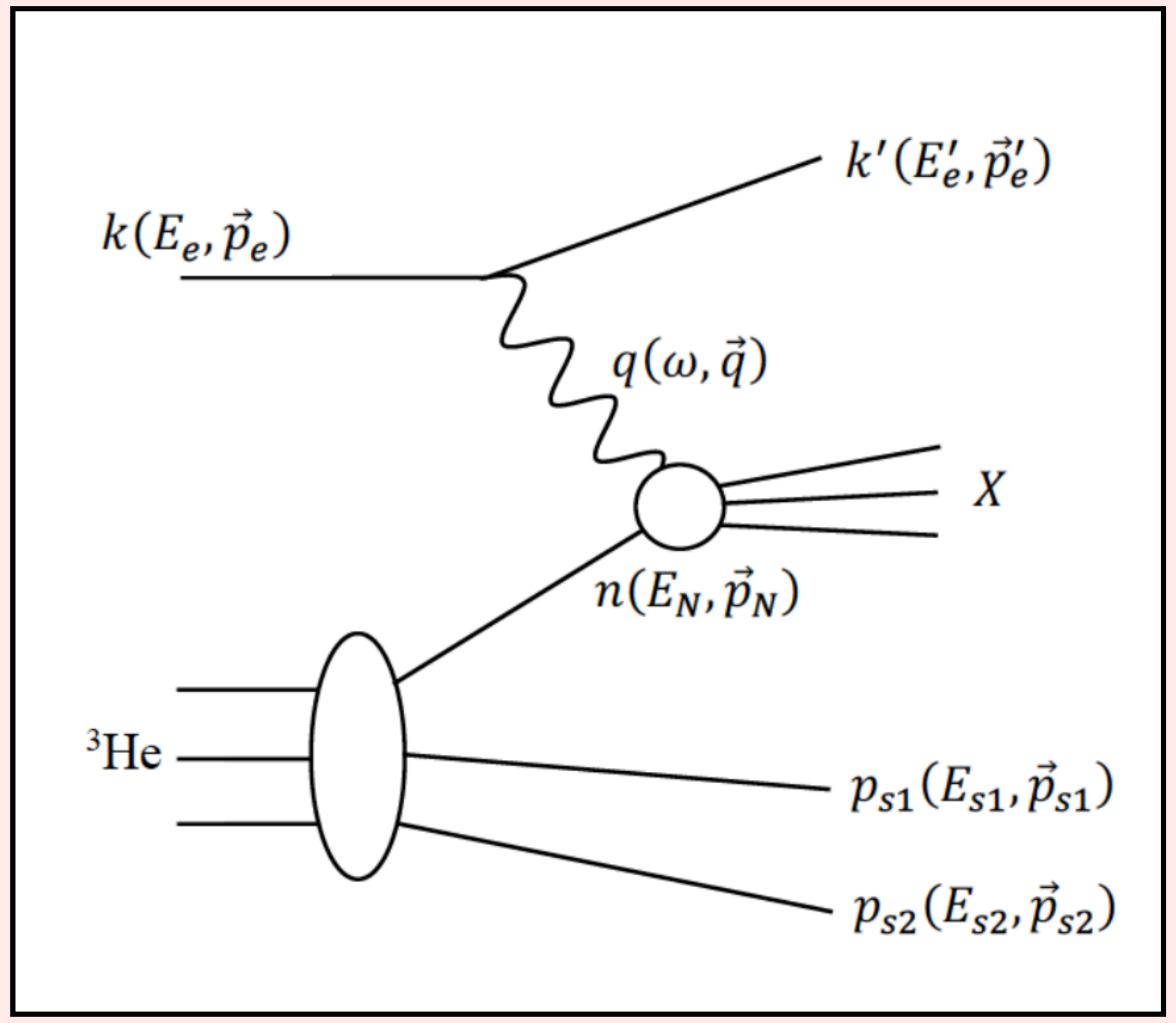
EIC Early Science

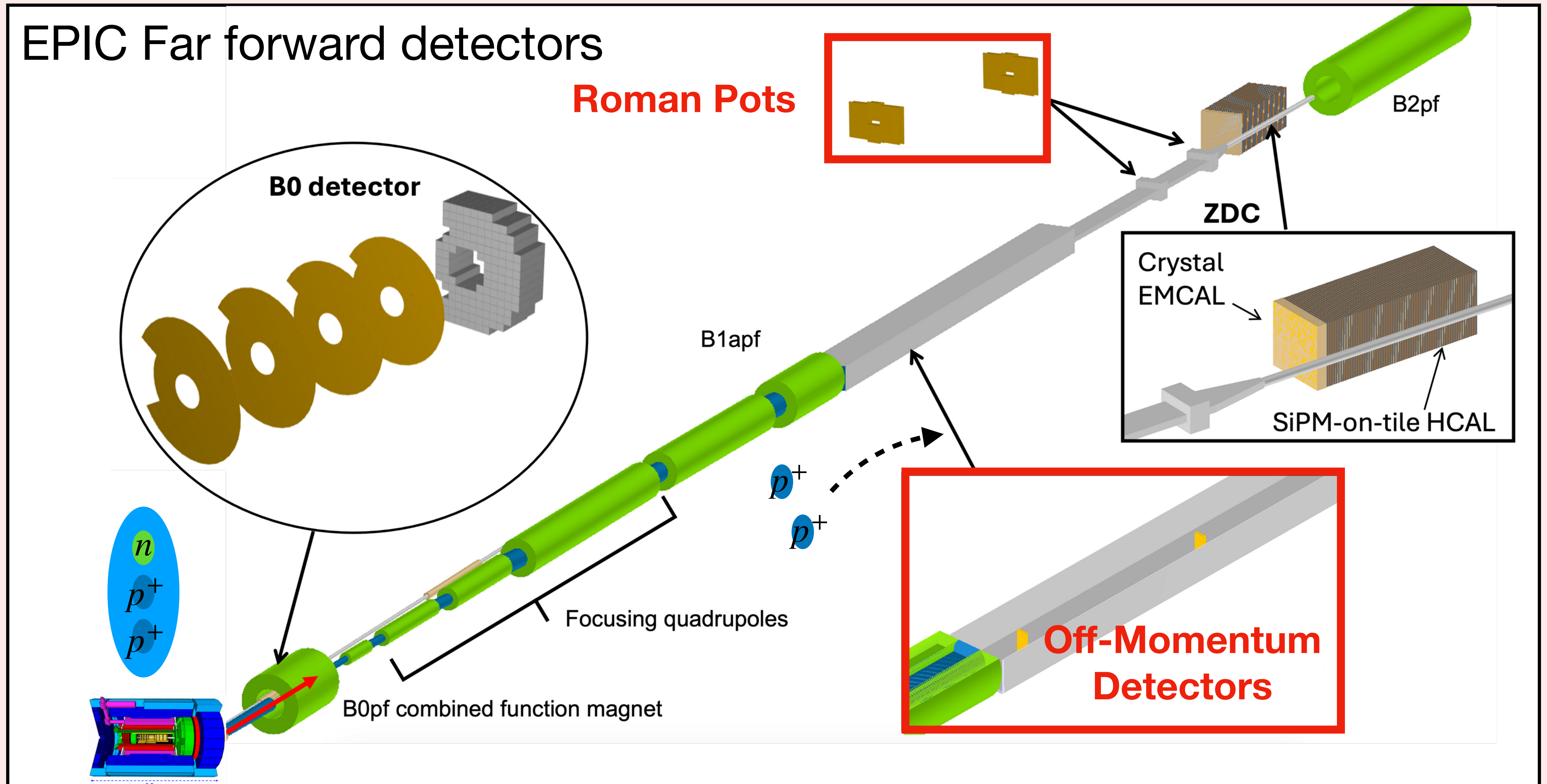
	Species	Energy (GeV)	Luminosity/year (fb-1)	Electron polarization	p/A polarization
YEAR 1	e+Ru or e+Cu	10 x 115	0.9	NO (Commissioning)	N/A
YEAR 2	e+D e+p	10 x 130	11.4 4.95 - 5.33	LONG	NO TRANS
YEAR 3	e+p	10 x 130	4.95 - 5.33	LONG	TRANS and/or LONG
YEAR 4	e+Au e+p	10 x 100 10 x 250	0.84 6.19 - 9.18	LONG	N/A TRANS and/or LONG
YEAR 5	e+Au e+3He	10 x 100 10 x 166	0.84 8.65	LONG	N/A TRANS and/or LONG

Note: the eA luminosity is per nucleon

A_1^n from e^3He DIS:

Diagram of the DIS process

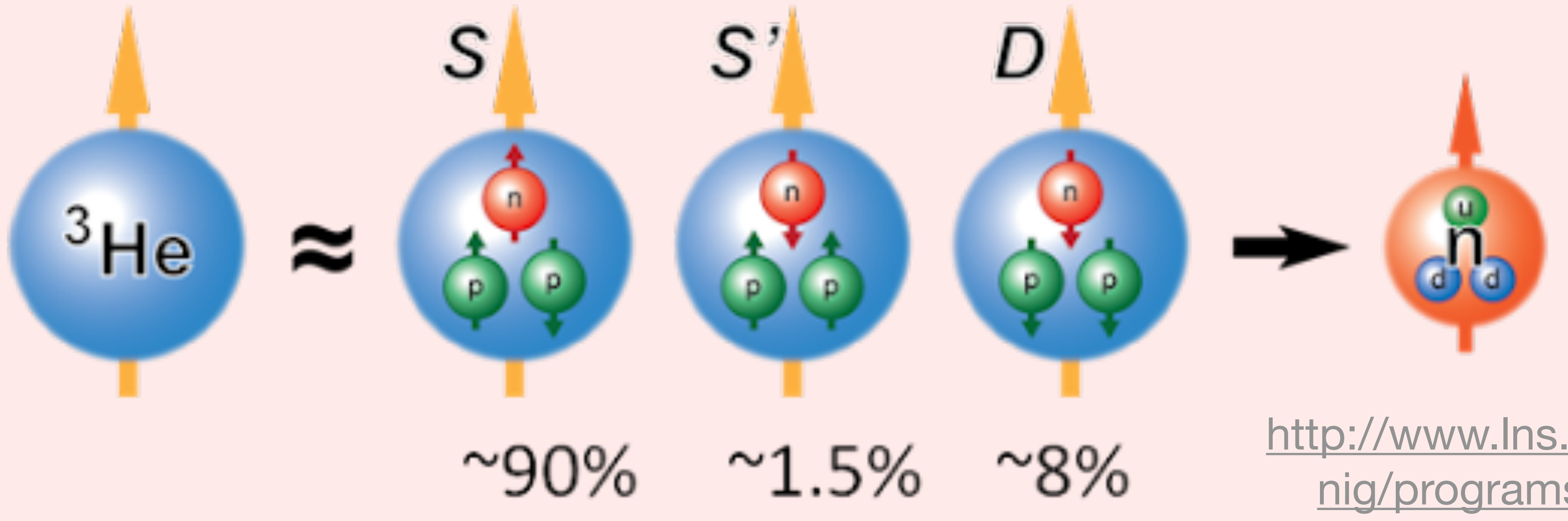




https://wiki.bnl.gov/EPIC/index.php?title=FarForward#/media/File:Far_forward_May_2024.png

A_1^n can be extracted indirectly via $A_1^{^3\mathrm{He}}$:

$$A_1^n = \frac{1}{P_n} \frac{F_2^{^3\mathrm{He}}}{F_2^n} \left(A_1^{^3\mathrm{He}} - 2P_p \frac{F_2^p}{F_2^{^3\mathrm{He}}} A_1^p \right)$$



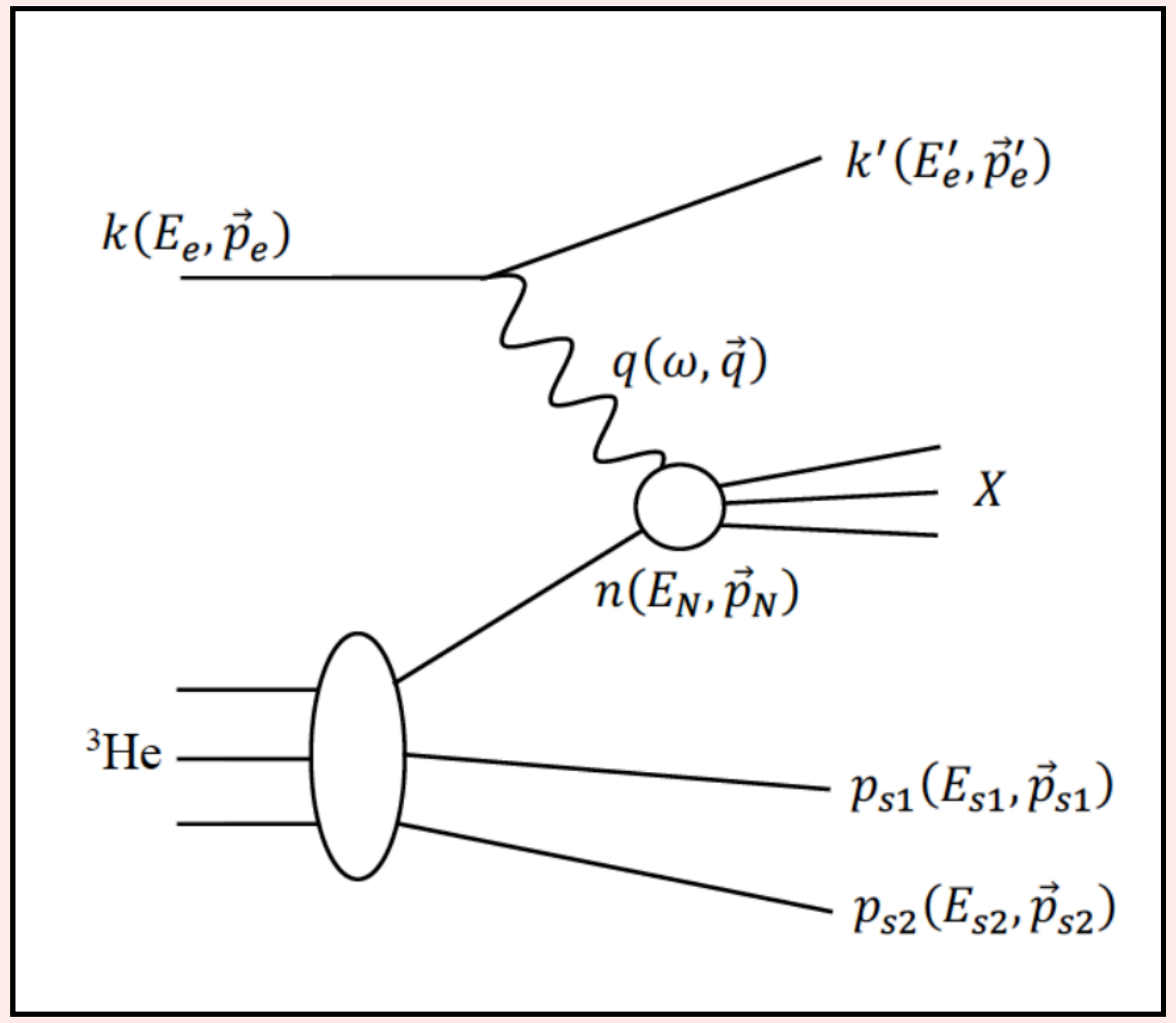
http://www.lns.mit.edu/nig/programs.html

$$P_n = 0.86 \pm 0.02$$

$$P_p = -0.028 \pm 0.004$$

A_1^n from $e\,^3$He DIS:

Diagram of the DIS process



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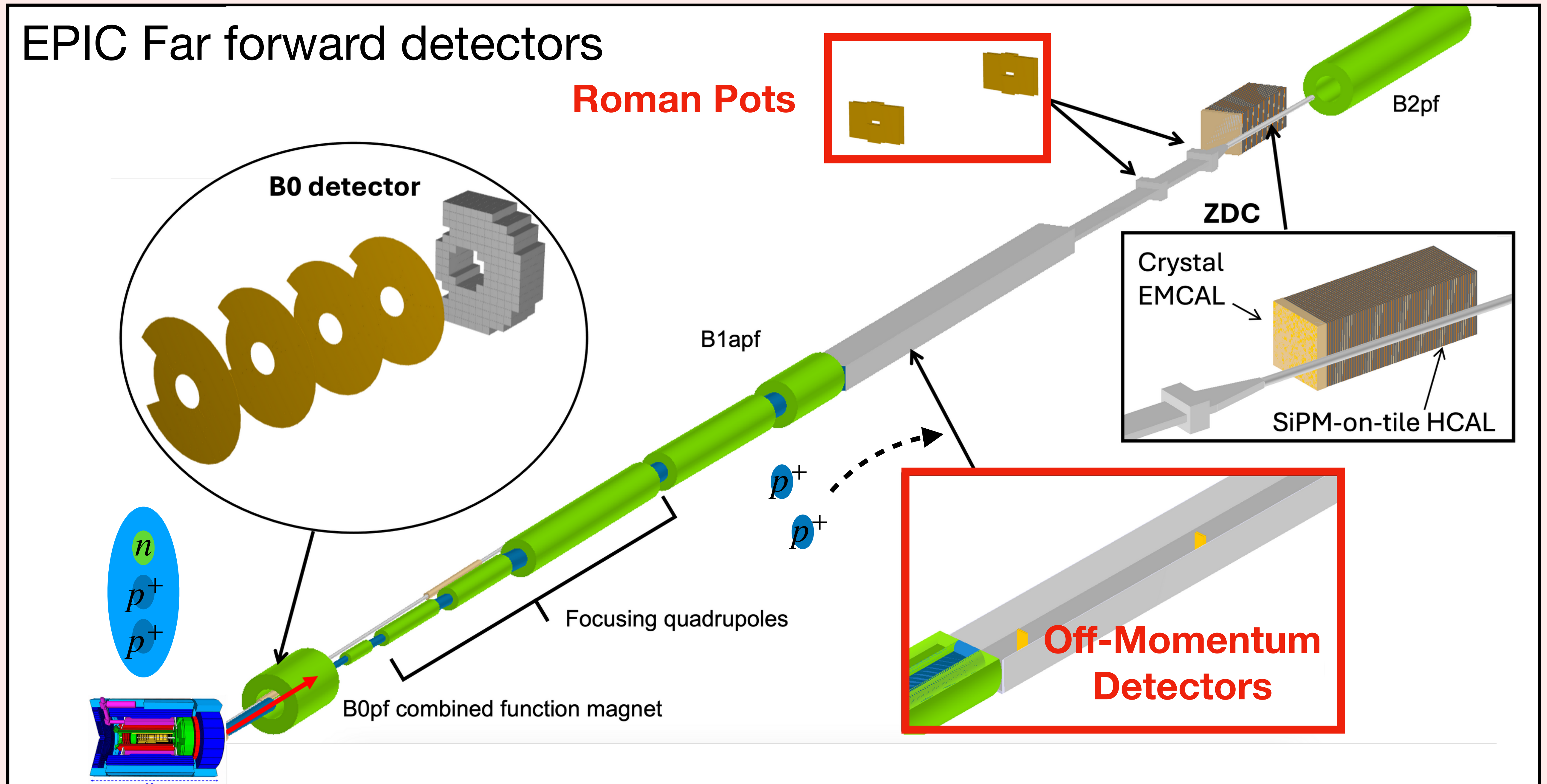

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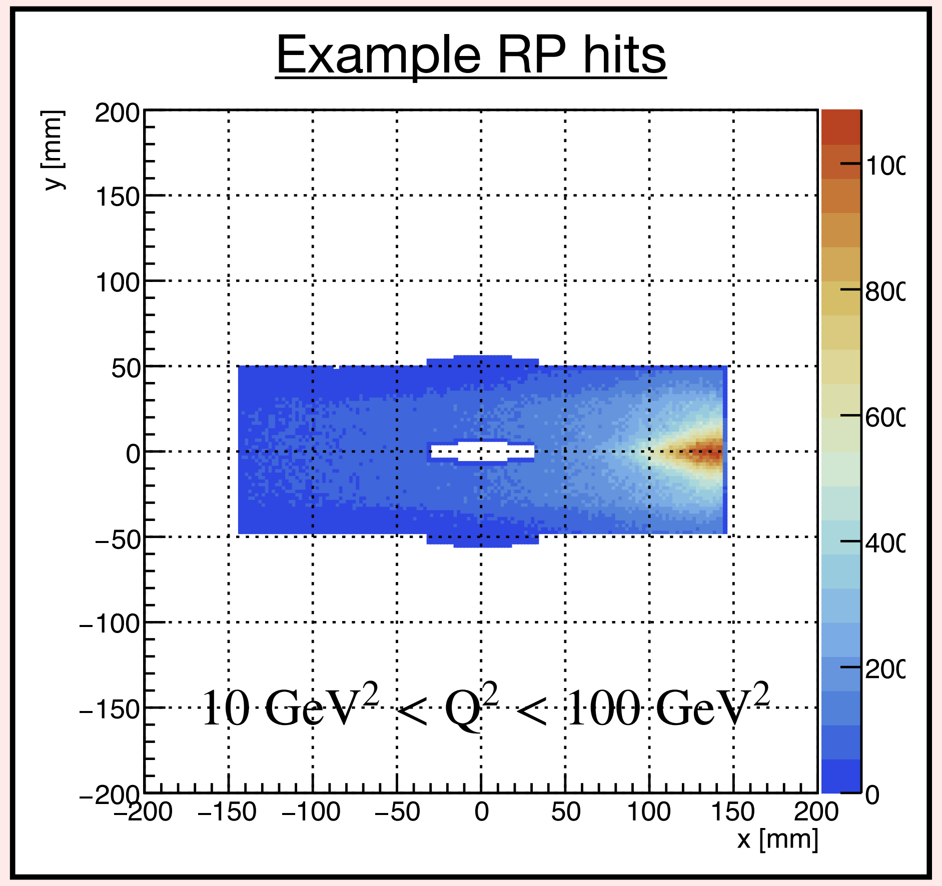
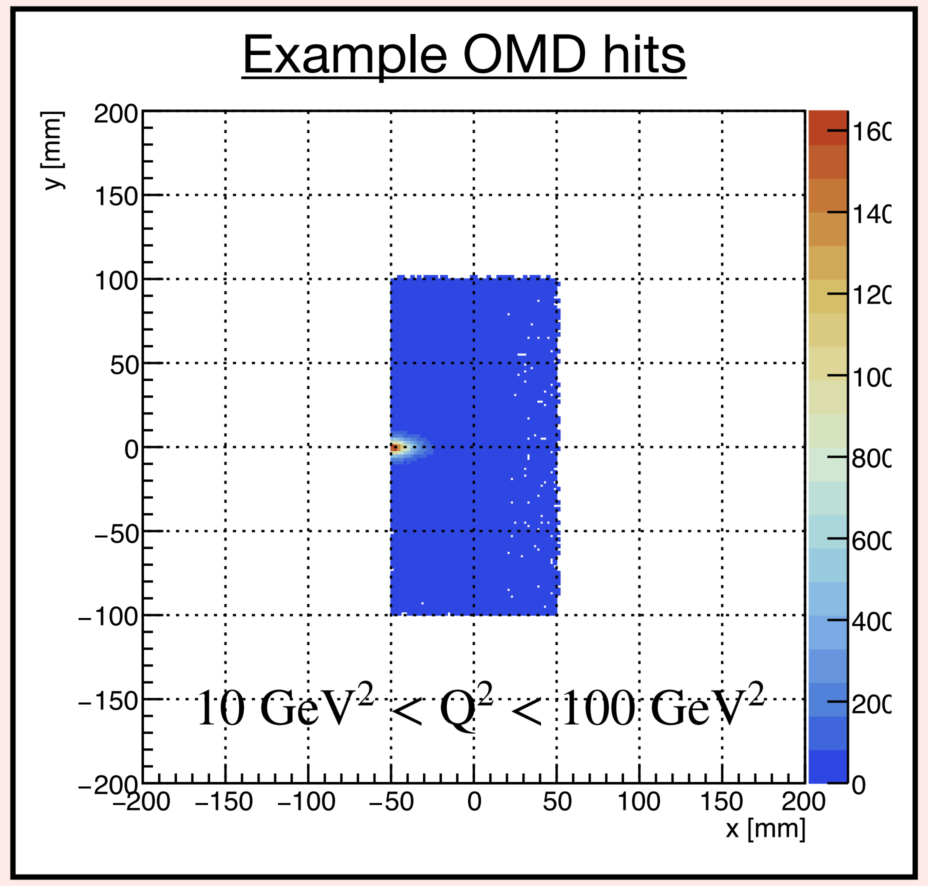
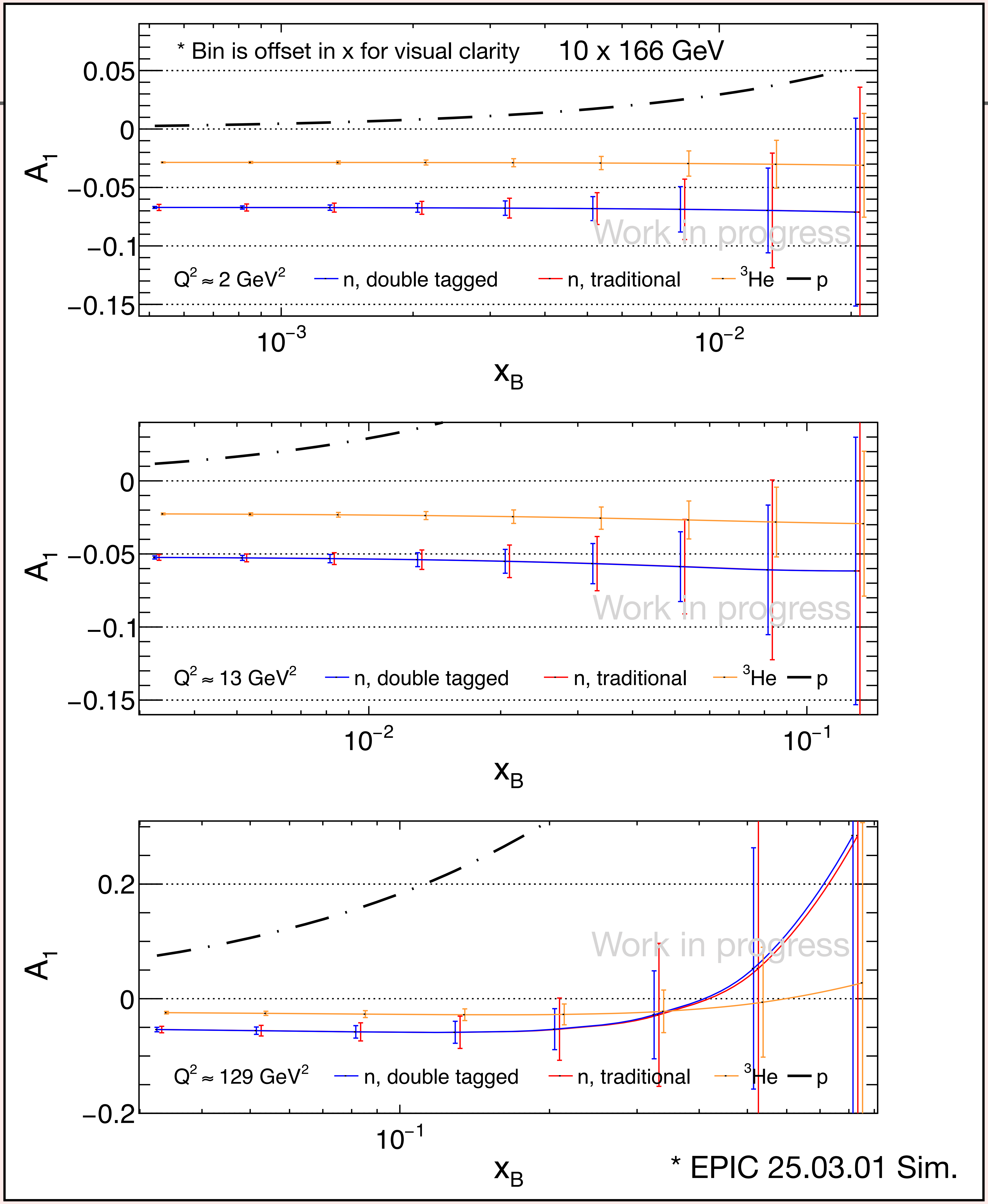
And **directly** by double spectator tagging:





A_1^n from e^3He DIS:

- $A_1(x, Q^2) \equiv \dfrac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \dfrac{A_\parallel}{D(1+\eta\xi)} - \dfrac{\eta A_\perp}{d(1+\eta\xi)}$
- $\mathscr{L} = 8.65\ \mathrm{fb}^{-1}, P_e = P_n = 70\,\%$
- Data split evenly between $A_\parallel$ and $A_\perp$
- $\delta A_{\parallel,\perp} = \dfrac{1}{\sqrt{N}P_e P_N}$
- $A_1^{^3\mathrm{He}} = P_n \dfrac{F_2^n}{F_2^{^3\mathrm{He}}} A_1^n + 2P_p \dfrac{F_2^p}{F_2^{^3\mathrm{He}}} A_1^p$
- Bin A_1^n calculated from: Doi: 10.2172/824895
- $F_2^{^3\mathrm{He}} = F_2^D + F_2^p$, all F_2's are taken from JAM22
- Correction not yet applied



A_1^n in early EIC science

- $A_1(x, Q^2) \equiv \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \frac{A_{\parallel}}{D(1+\eta\xi)} - \frac{\eta A_{\perp}}{d(1+\eta\xi)}$
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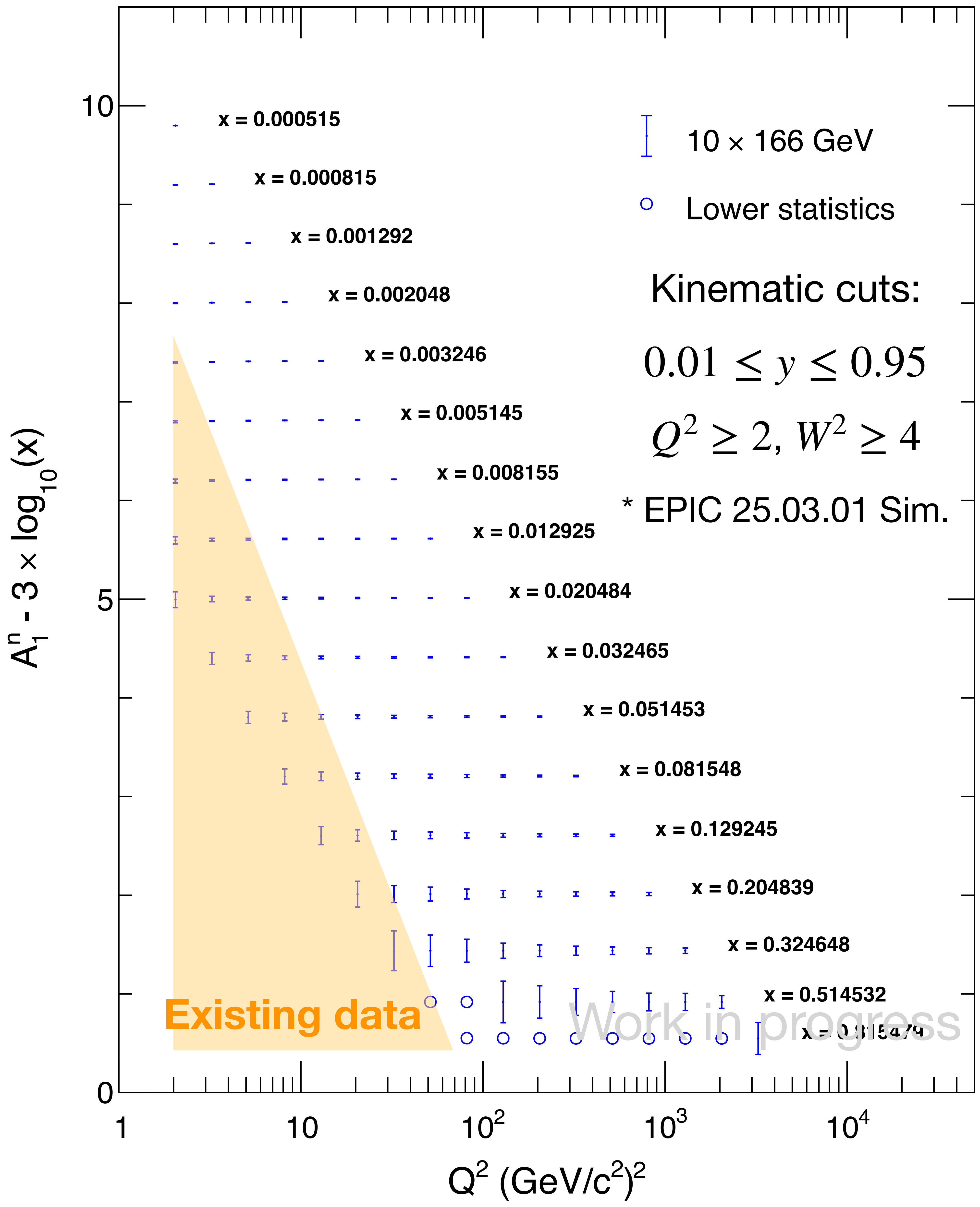
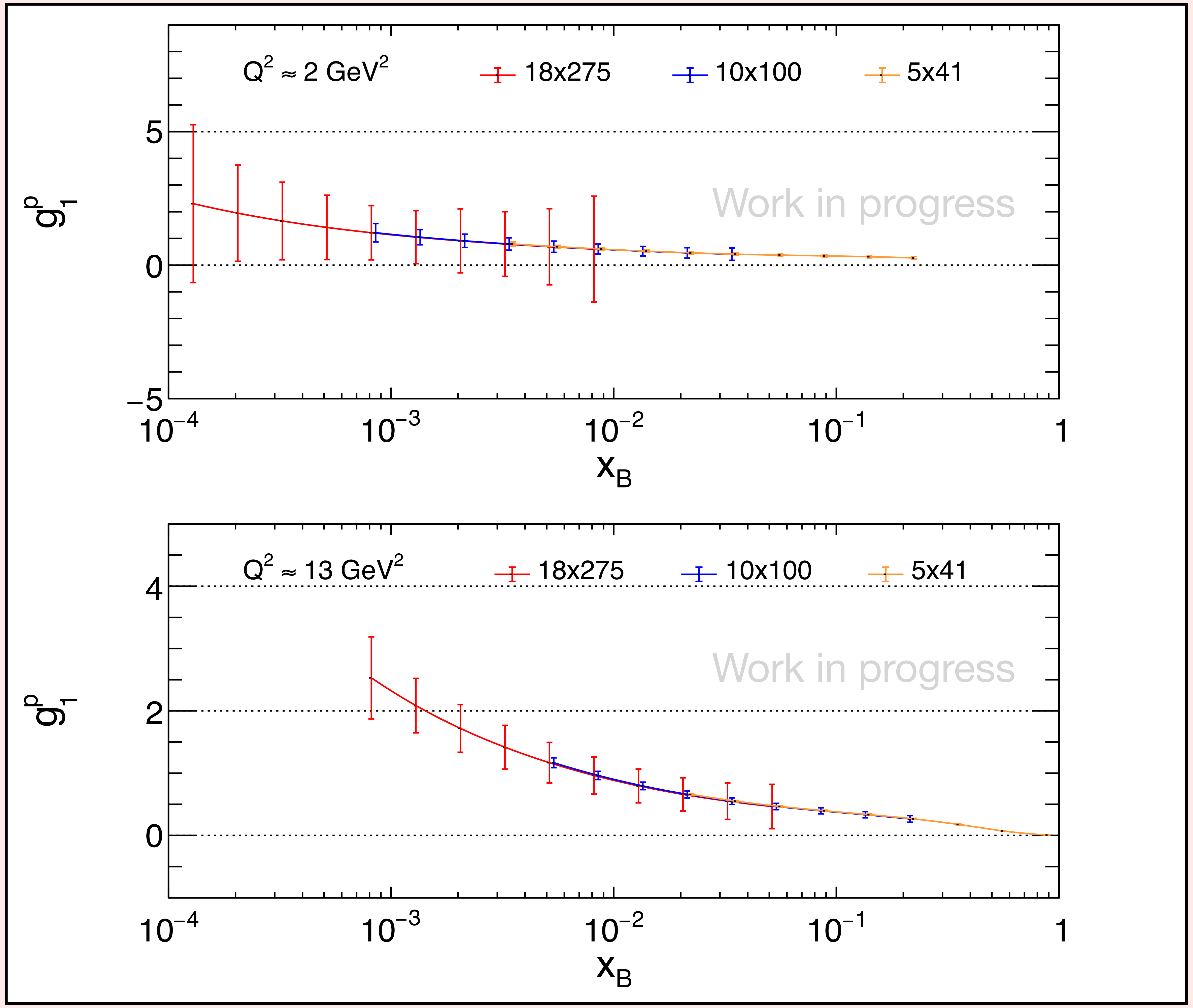
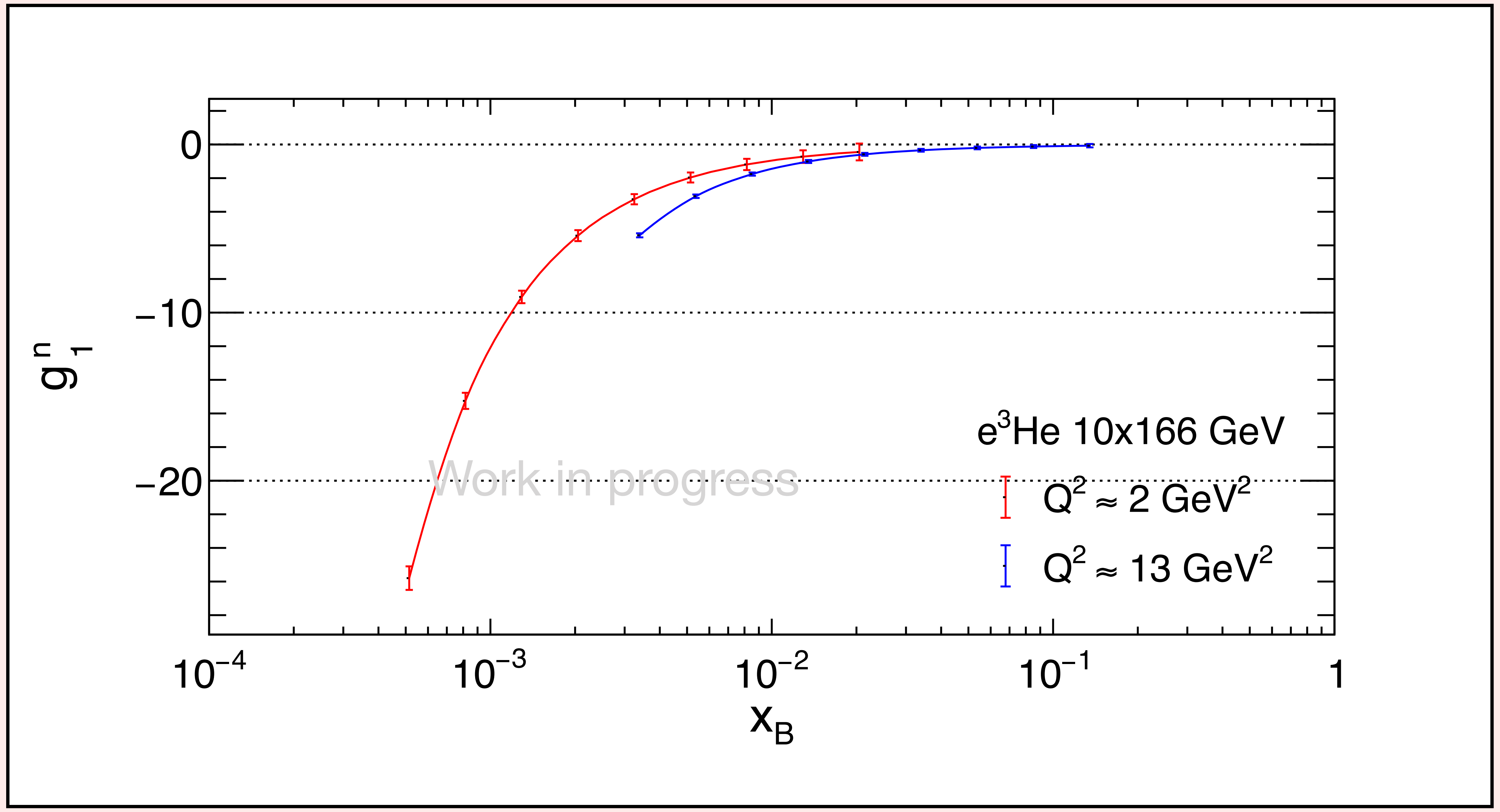
- Data split evenly between $A_{\parallel}$ and $A_{\perp}$
- $\delta A_{\parallel,\perp} = \frac{1}{\sqrt{N P_e P_N}}$
- Bin A_1 calculated from: Doi: 10.2172/824895
- Statistical uncertainty only, correction not yet applied



g_1^p and g_1^n

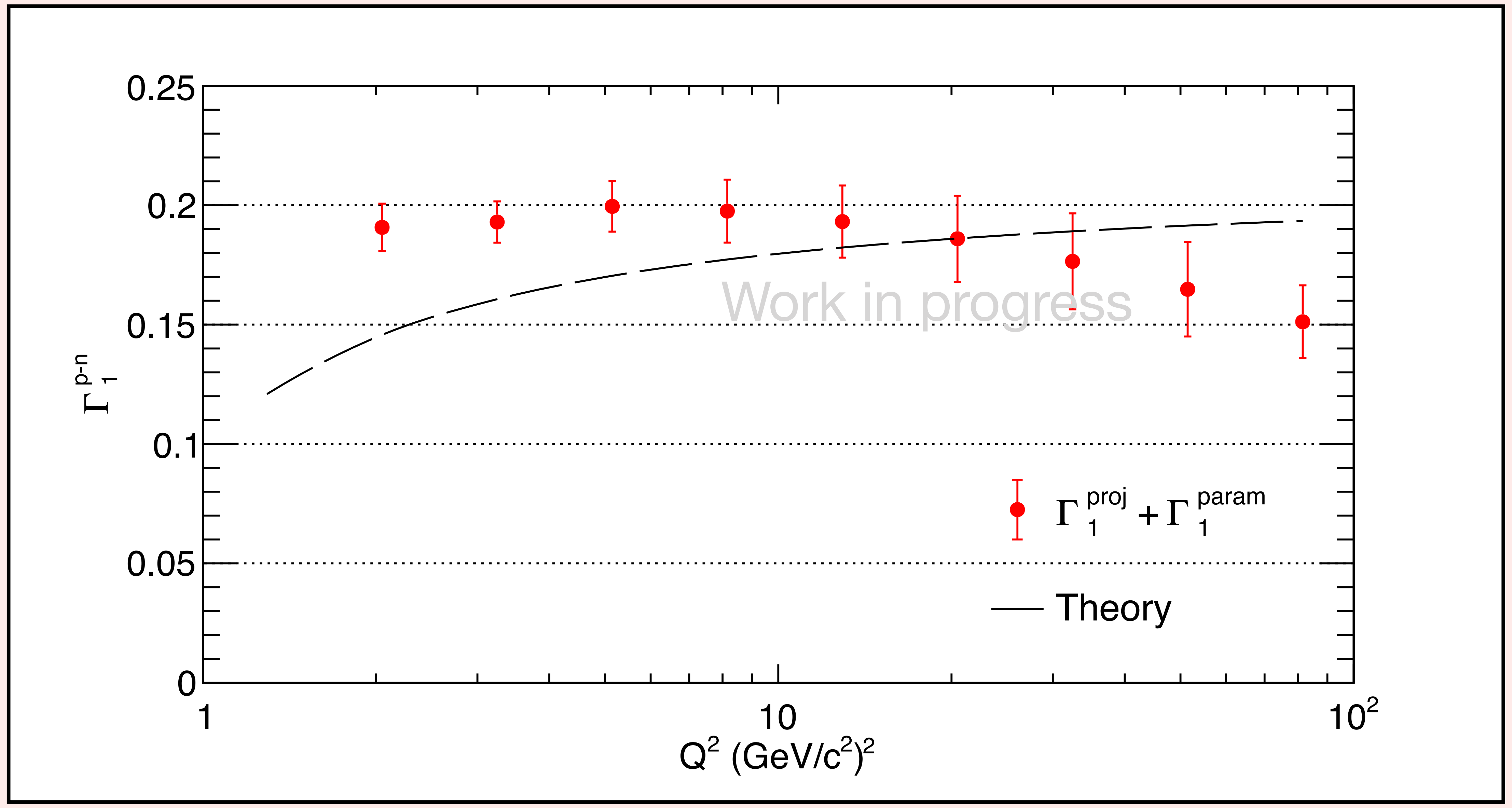
- $A_1 \approx g_1/F_1$ with F_1 calculated from JAM22
- Statistical + F_1 uncertainties. Other uncertainties and corrections are not yet applied

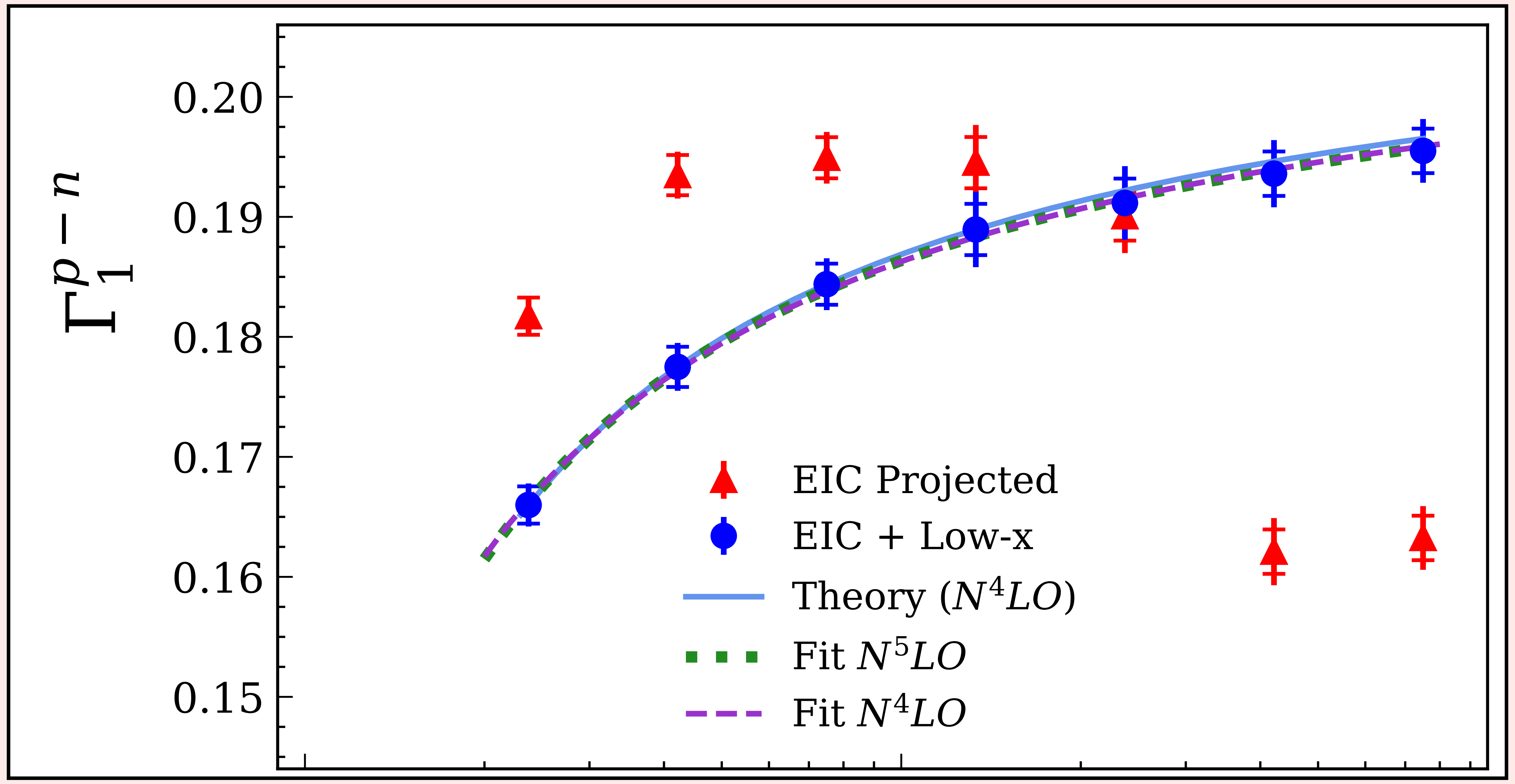




g_1^p and g_1^n

- $A_1 \approx g_1/F_1$ with F_1 calculated from JAM22
- Statistical + F_1 uncertainties. Other uncertainties and corrections are not yet applied
- $\Gamma_1^{\mathrm{p-n}} \equiv \int_0^{1^-} (g_1^p - g_1^n)\, dx$





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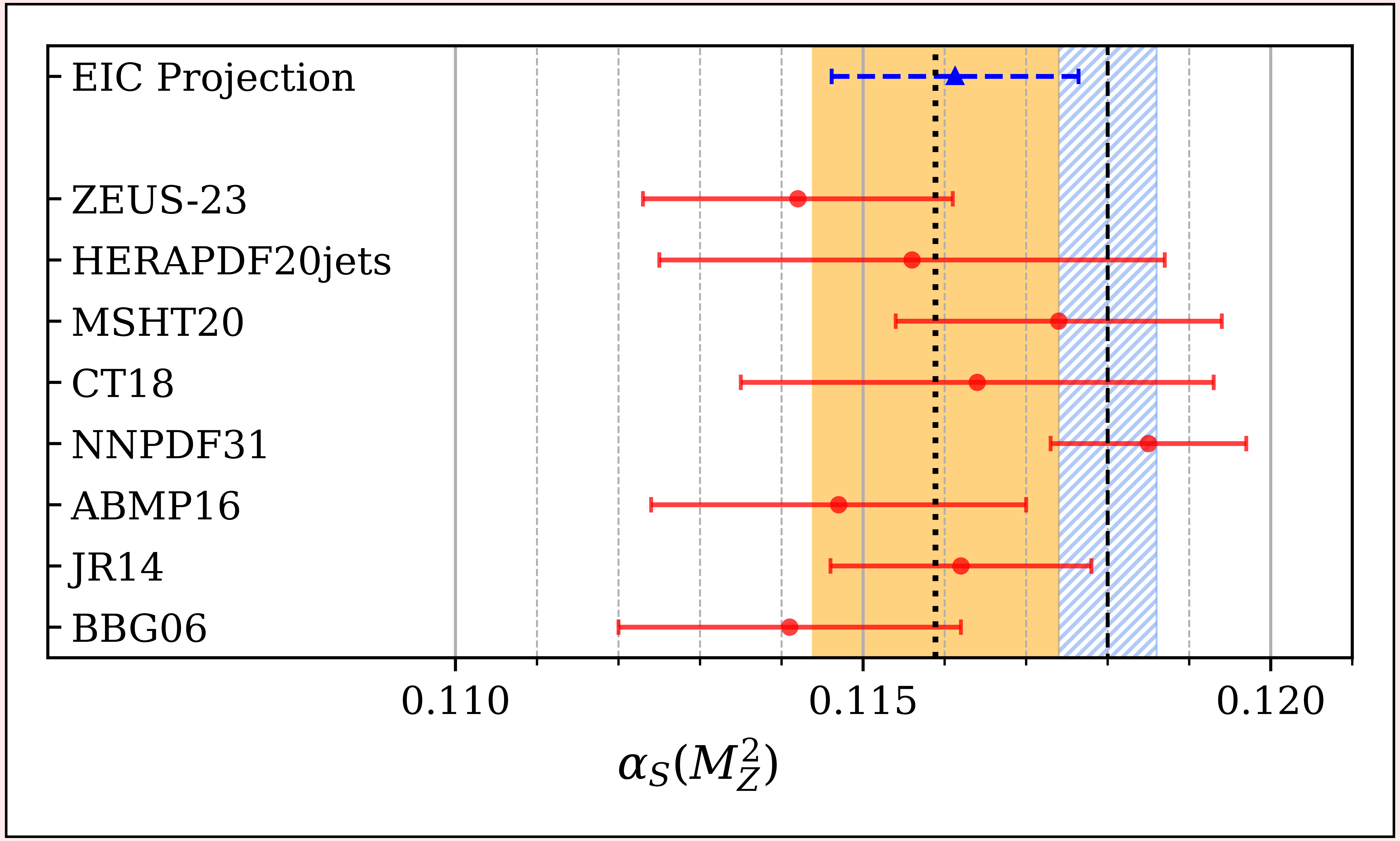
Thank you!



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