Progress on double spin asymmetry, g_1^p, g_1^n projection study

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Motivation and Method

Spin composition:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L^q + L^g$$

Quark-Parton Model:

$$\Gamma_1^{p(n)} = \int_0^1 \boxed{g_1^{p(n)}}\, dx = \frac{1}{12}\left[+(-)a_3 + \frac{1}{3}a_8\right] + \frac{1}{9}a_0$$

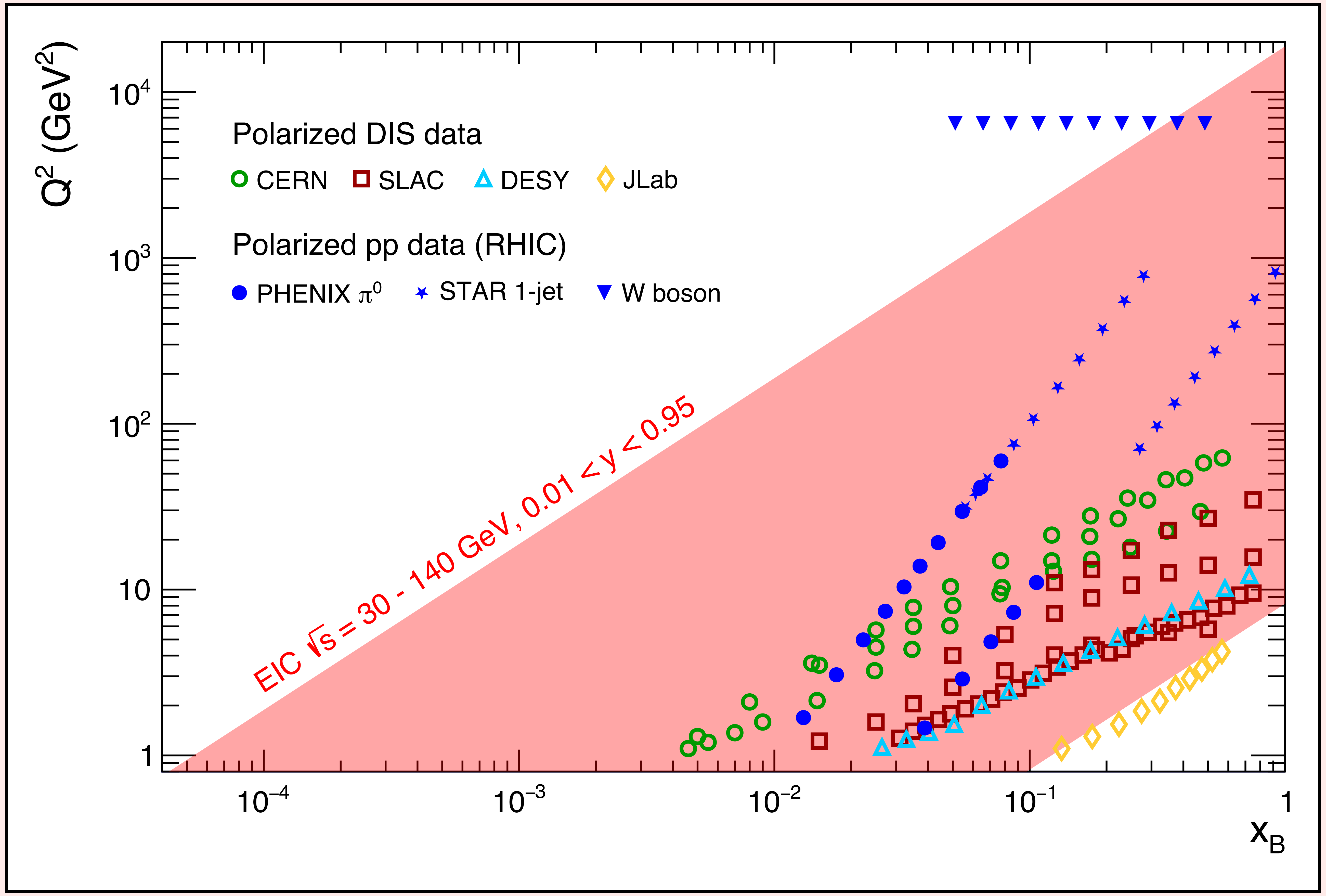
$$a_0 = \Delta u + \Delta d + \Delta s \equiv \Delta\Sigma$$

$$a_3 = \Delta u - \Delta d = \left|\frac{g_A}{g_V}\right|$$

$$a_8 = \Delta u + \Delta d - 2\Delta s$$

Bjorken sum:

$$\Gamma_1^{\mathrm{p}}(Q^2, x) - \Gamma_1^{\mathrm{n}}(Q^2, x) = \sum_{\tau>0} \frac{\mu_{2\tau}^{p-n}(\alpha_S)}{Q^{2\tau-2}}$$



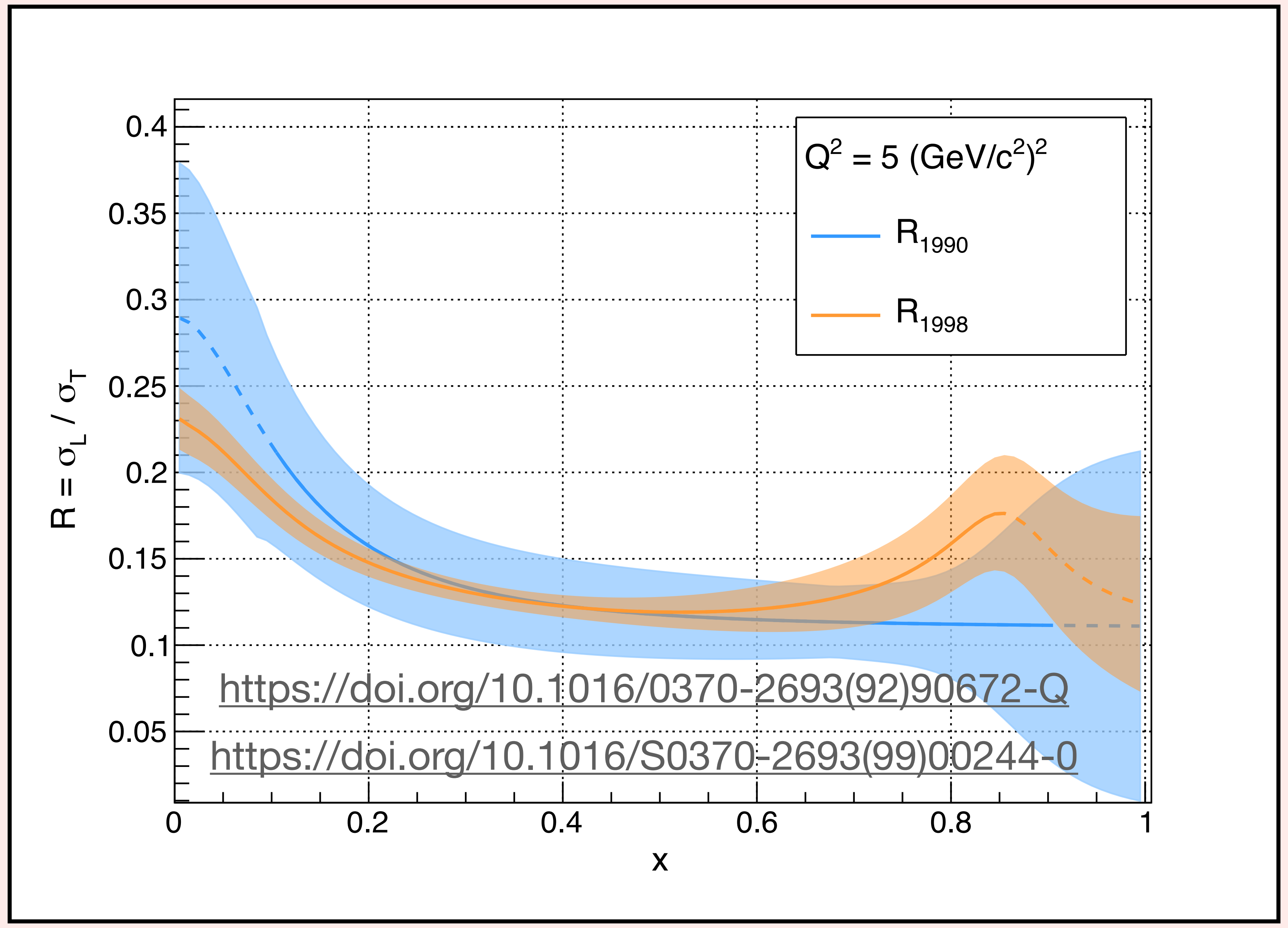
Motivation and Method

$$g_1 = \frac{F_2}{2x(1+R)}(A_1 + \gamma A_2)$$

$$A_1(x, Q^2) \equiv \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \frac{A_\parallel}{D(1+\eta\xi)} - \frac{\eta A_\perp}{d(1+\eta\xi)}$$

$$A_2 = \frac{2\sigma^{\mathrm{TL}}}{\sigma_{1/2} + \sigma_{3/2}}$$

$$A_\parallel = \frac{\sigma_{\downarrow\Uparrow} - \sigma_{\uparrow\Uparrow}}{\sigma_{\downarrow\Uparrow} + \sigma_{\uparrow\Uparrow}} \qquad A_\perp = \frac{\sigma_{\downarrow\Rightarrow} - \sigma_{\uparrow\Rightarrow}}{\sigma_{\downarrow\Rightarrow} + \sigma_{\uparrow\Rightarrow}}$$



$$\gamma^2 = \frac{4M^2x^2}{Q^2} \qquad D = \frac{y(2-y)(2+\gamma^2 y)}{2(1+\gamma^2)y^2 + (4(1-y) - \gamma^2 y^2)(1+R)}$$

$$d = \frac{D\sqrt{4(1-y) - \gamma^2 y^2}}{2-y} \qquad R \equiv \frac{\sigma_L}{\sigma_T}$$

$$\eta = \frac{4(1-y) - \gamma^2 y^2}{(2-y)(2+\gamma^2 y)} \qquad \xi = \frac{\gamma(2-y)}{2+\gamma^2 y}$$

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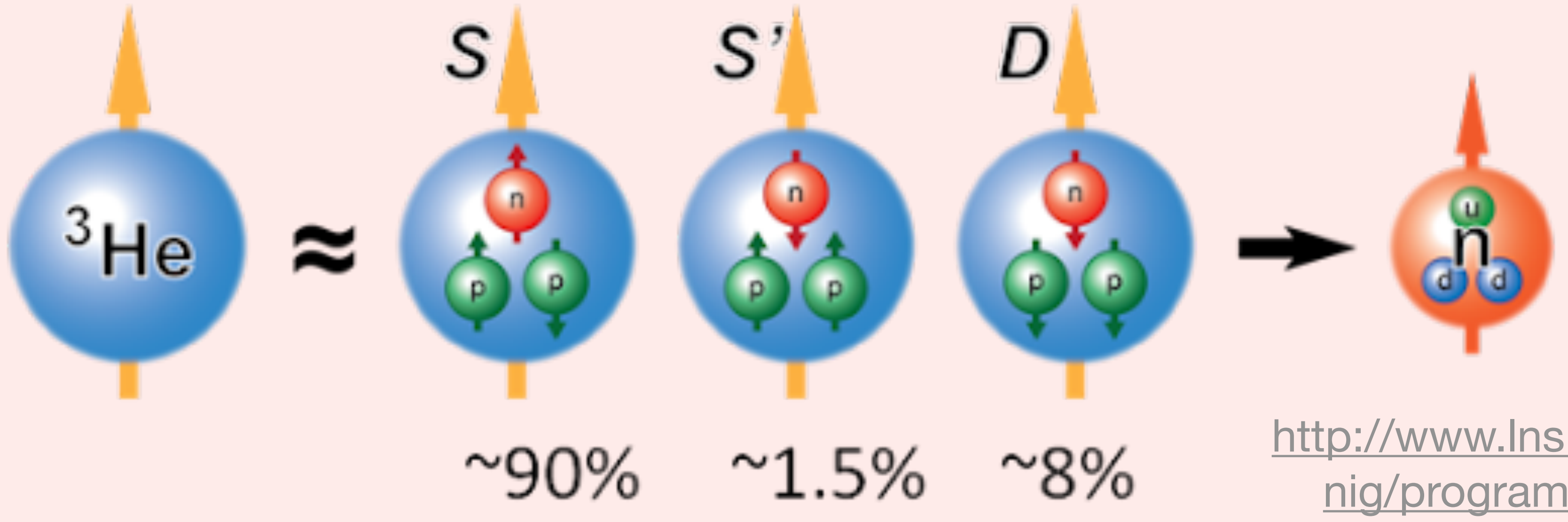
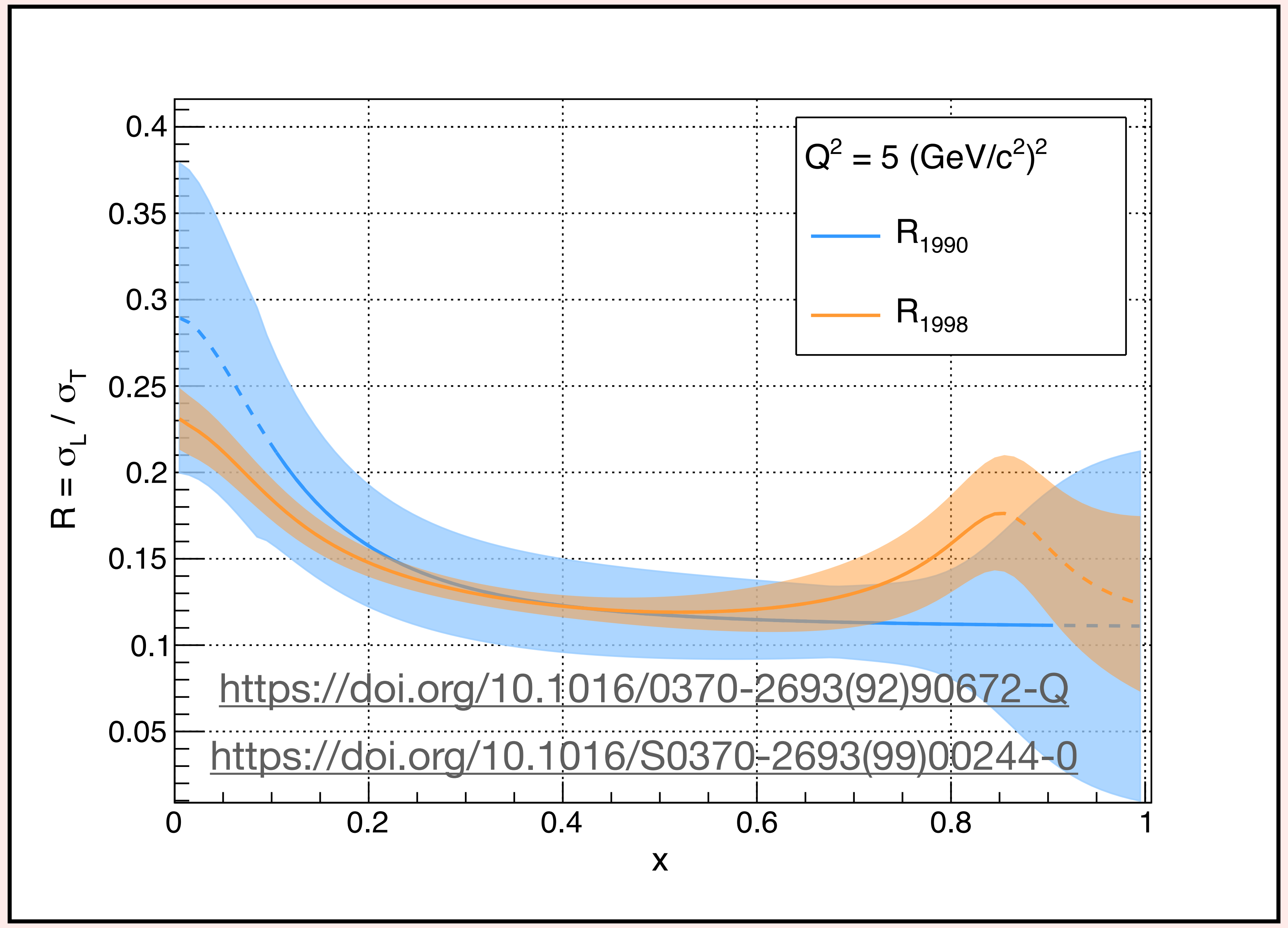


http://www.lns.mit.edu/nig/programs.html



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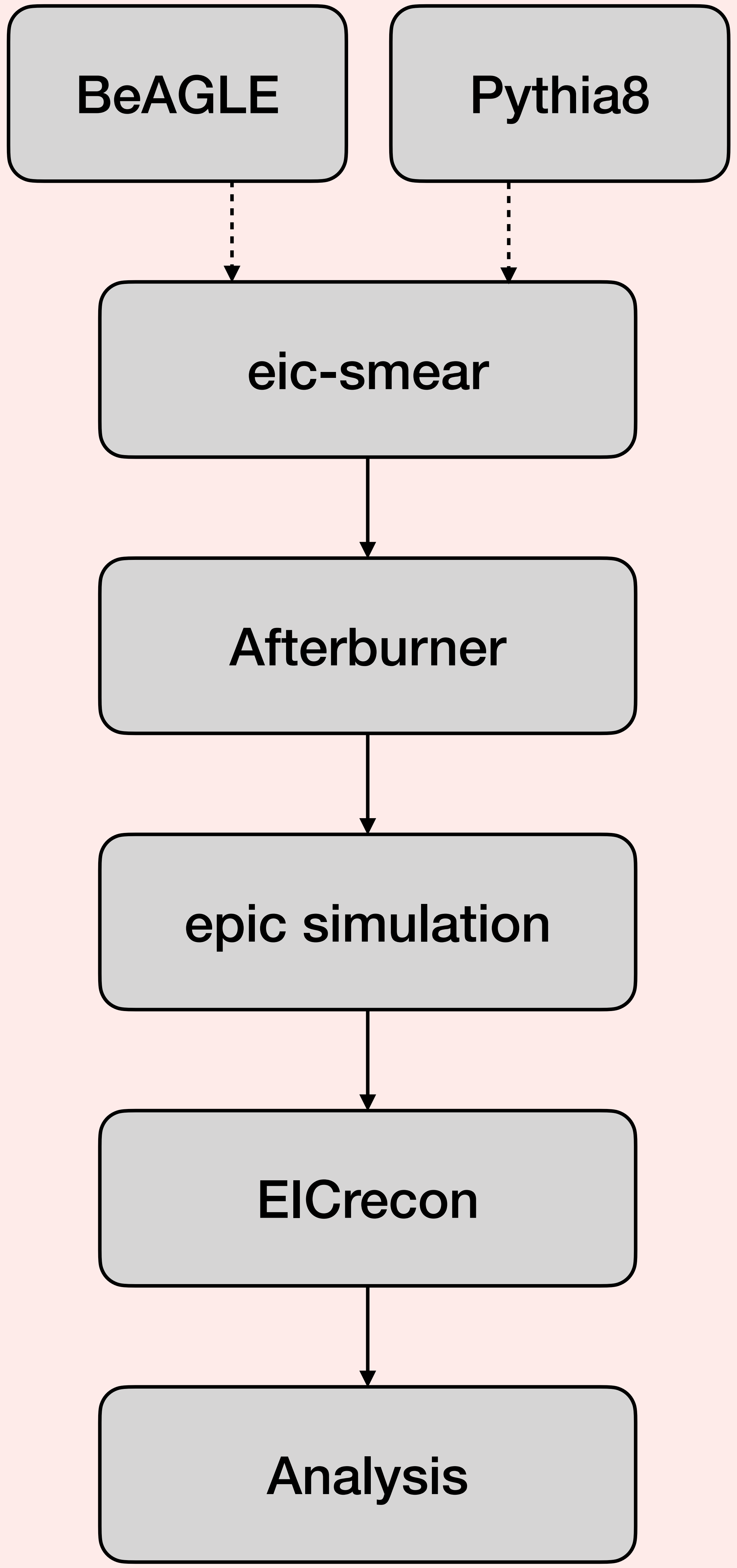
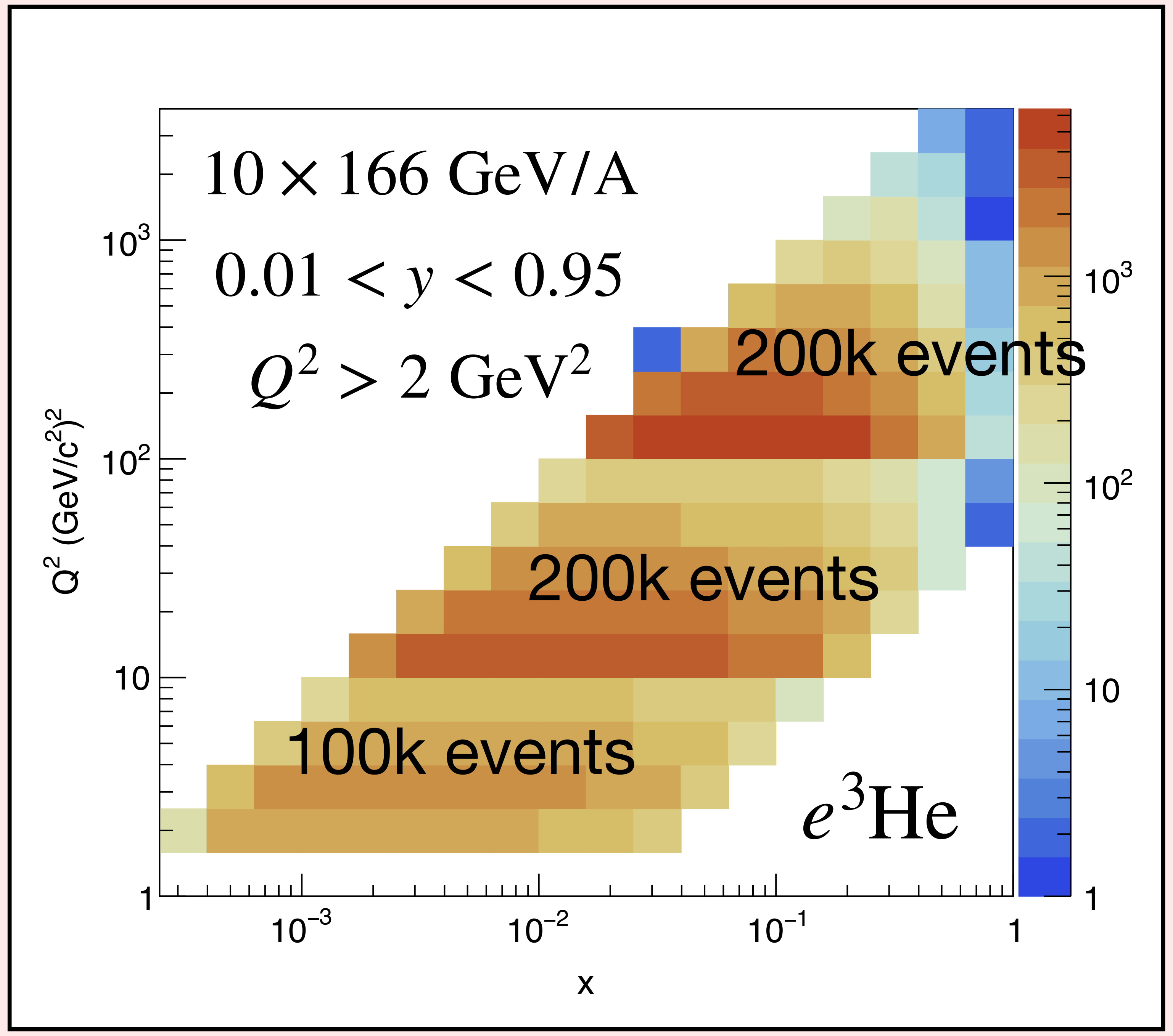
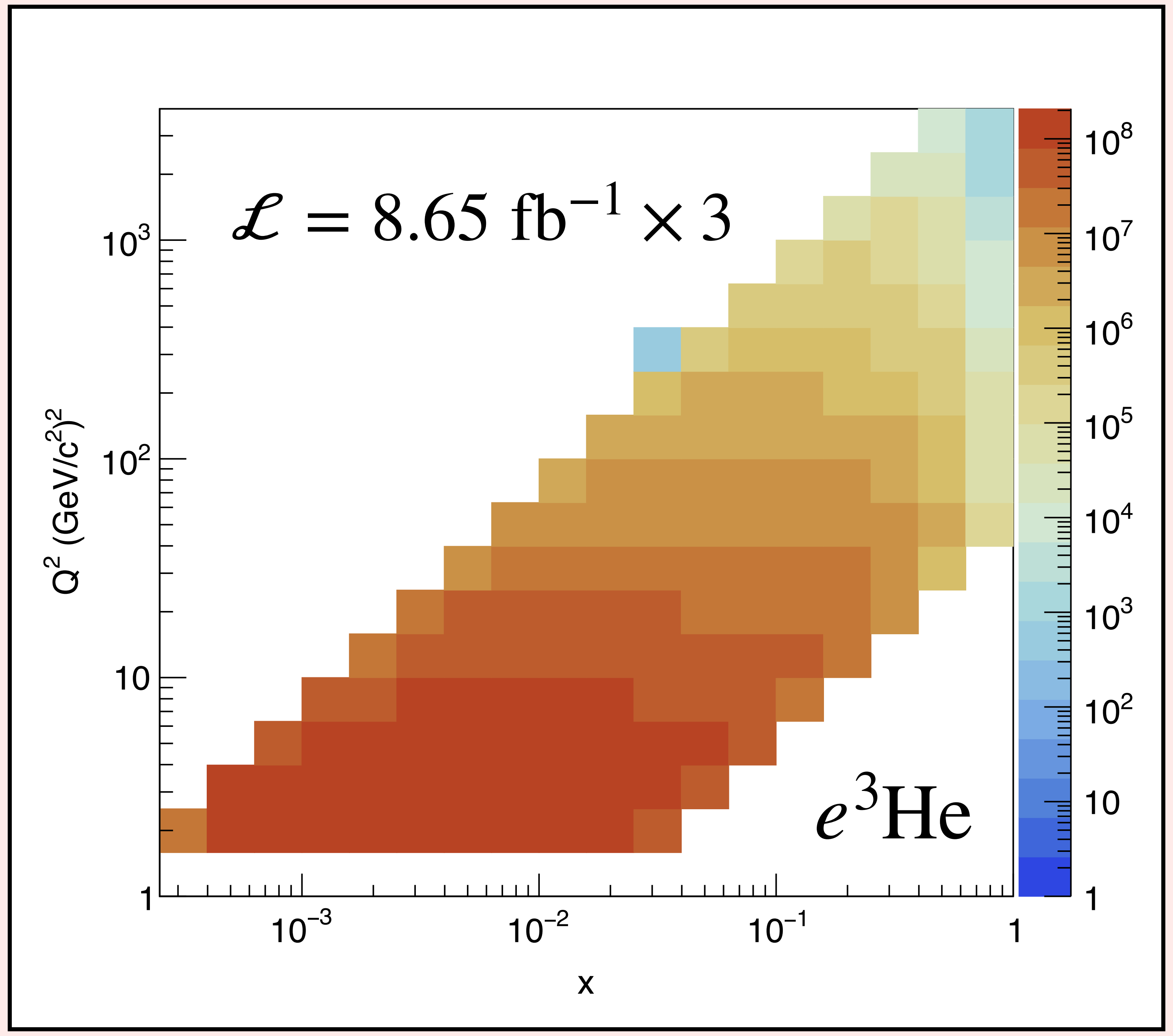
Analysis procedure



<u>Example of event scaling</u>



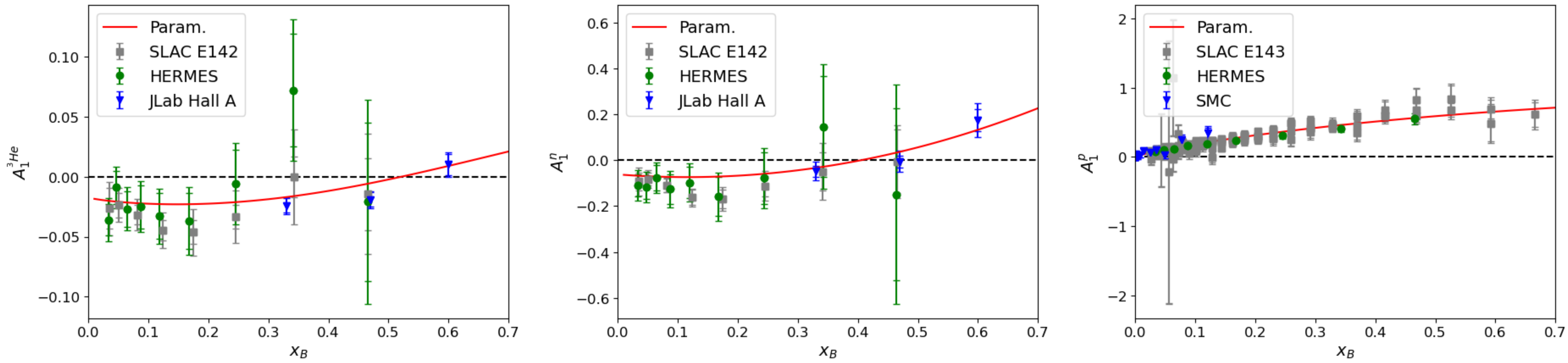


generated events → scaled to planned luminosity

- **Current event generator used are for non-polarized DIS**
- **Estimate statistical uncertainty with** $\delta A_{\parallel,\perp} = \dfrac{1}{\sqrt{N} P_e P_N}$

Parameterization for A_1

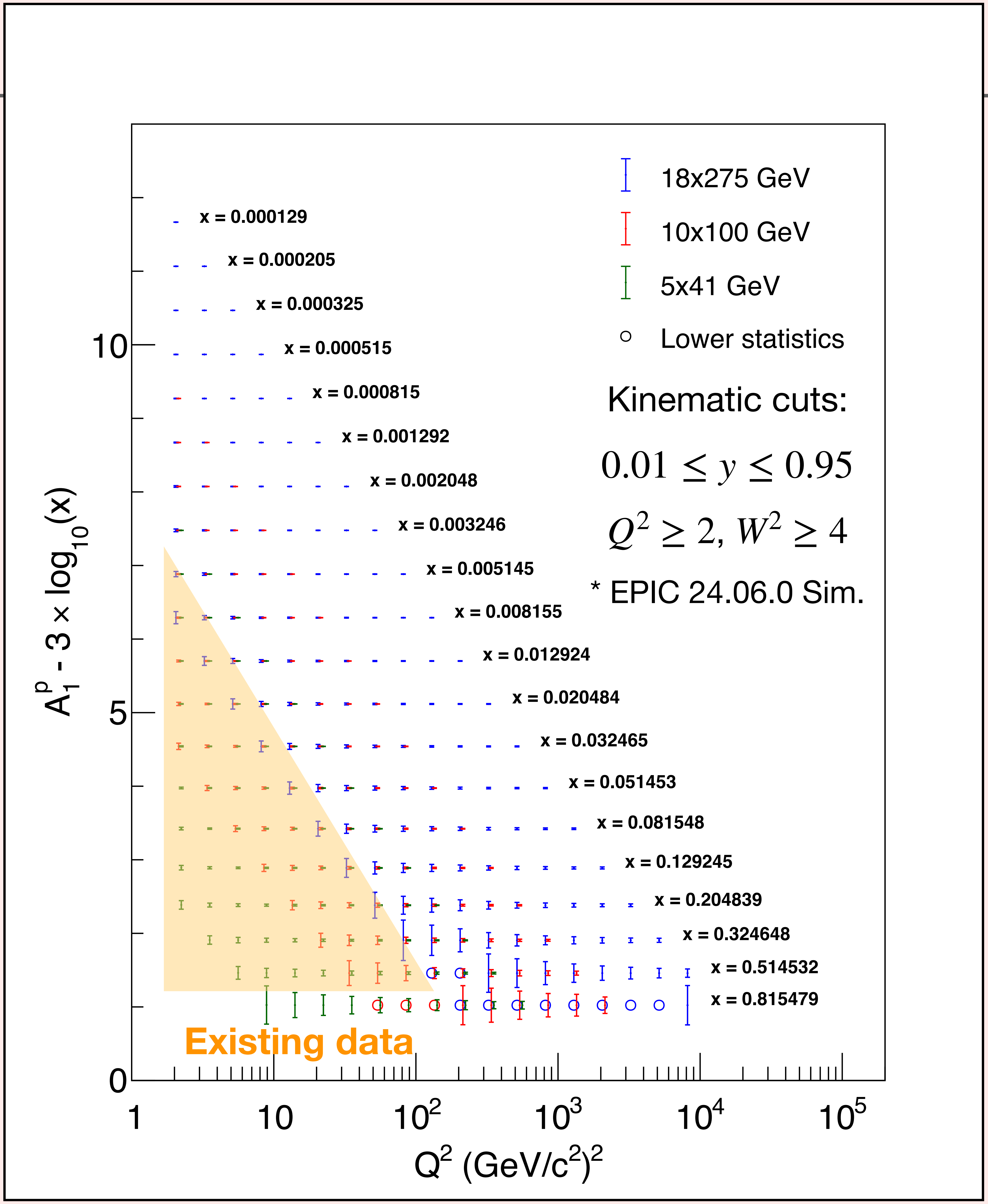
- A_1^p and A_1^n calculated from: Doi: 10.2172/824895
- all F_2's are taken from JAM22
- $A_1^{^3\mathrm{He}} = P_n \frac{F_2^n}{F_2^{^3\mathrm{He}}} A_1^n + 2P_p \frac{F_2^p}{F_2^{^3\mathrm{He}}} A_1^p \qquad P_p = -0.028 \pm 0.004 \qquad P_n = 0.86 \pm 0.02$



- Parameterization at $Q^2 = 2.88\ \mathrm{GeV}^2$
- Data points are at various Q^2 with majority $< 5\ \mathrm{GeV}^2$

A_1^p from ep DIS

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



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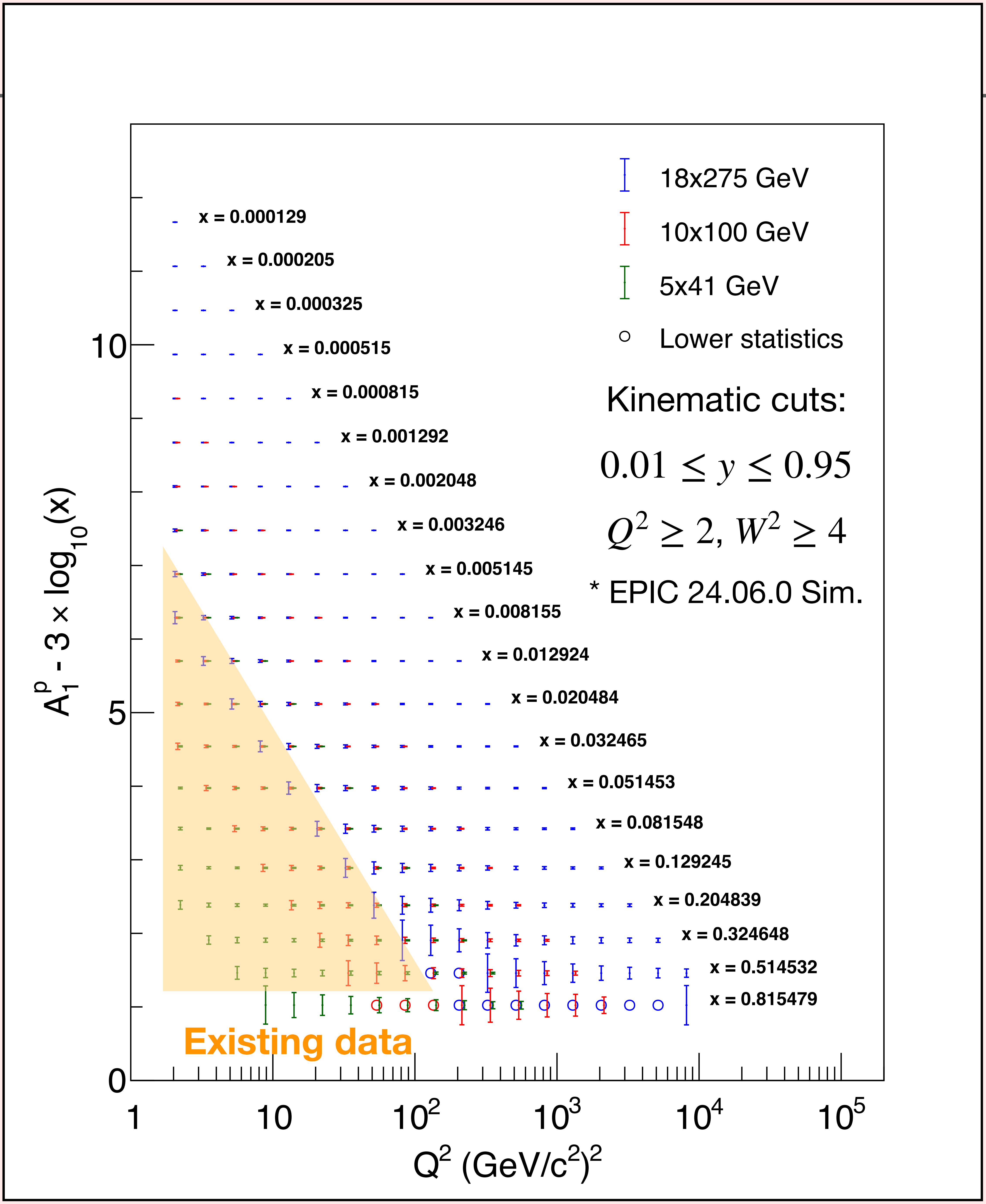

EIC Early Science

	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
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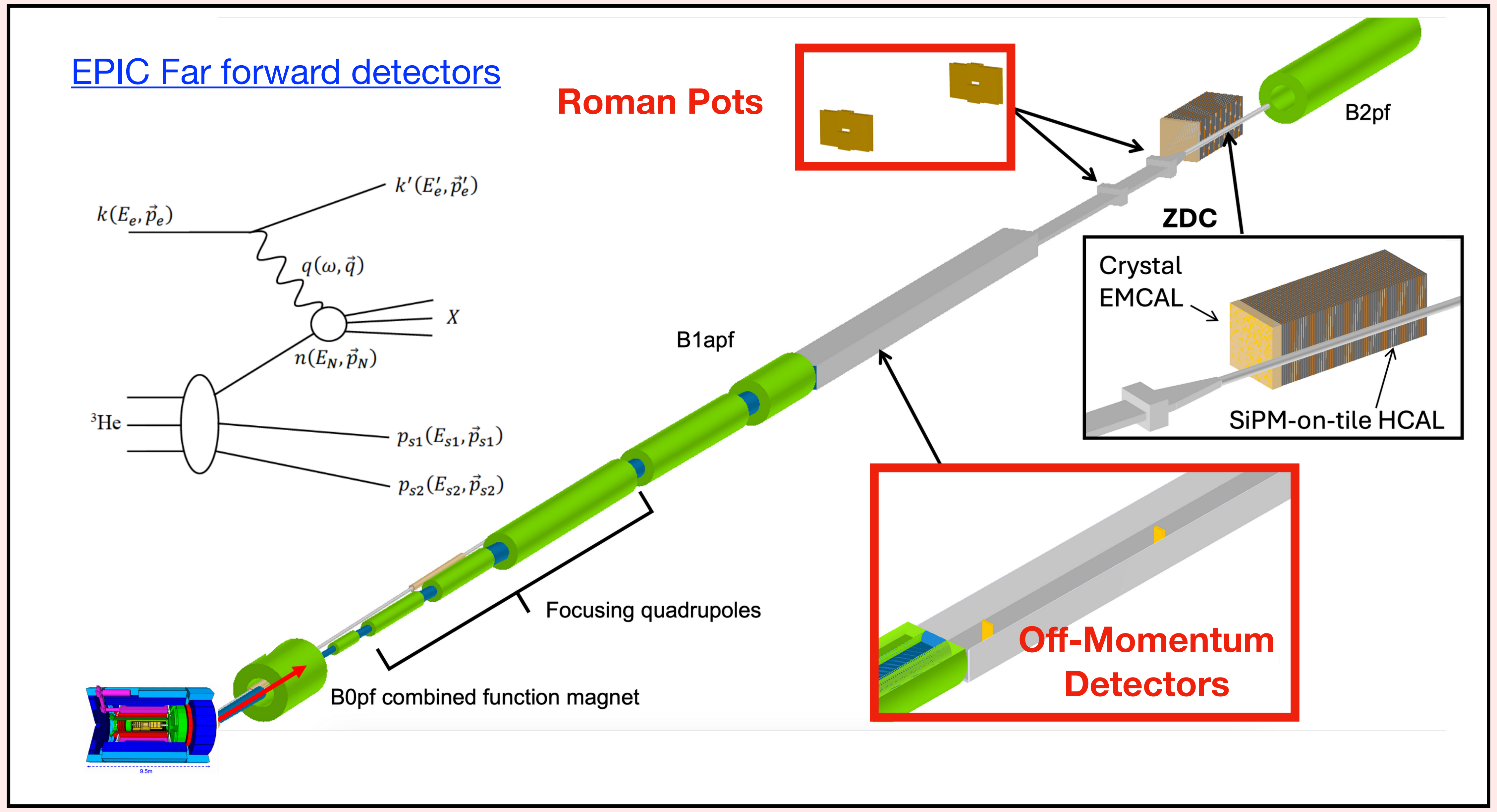
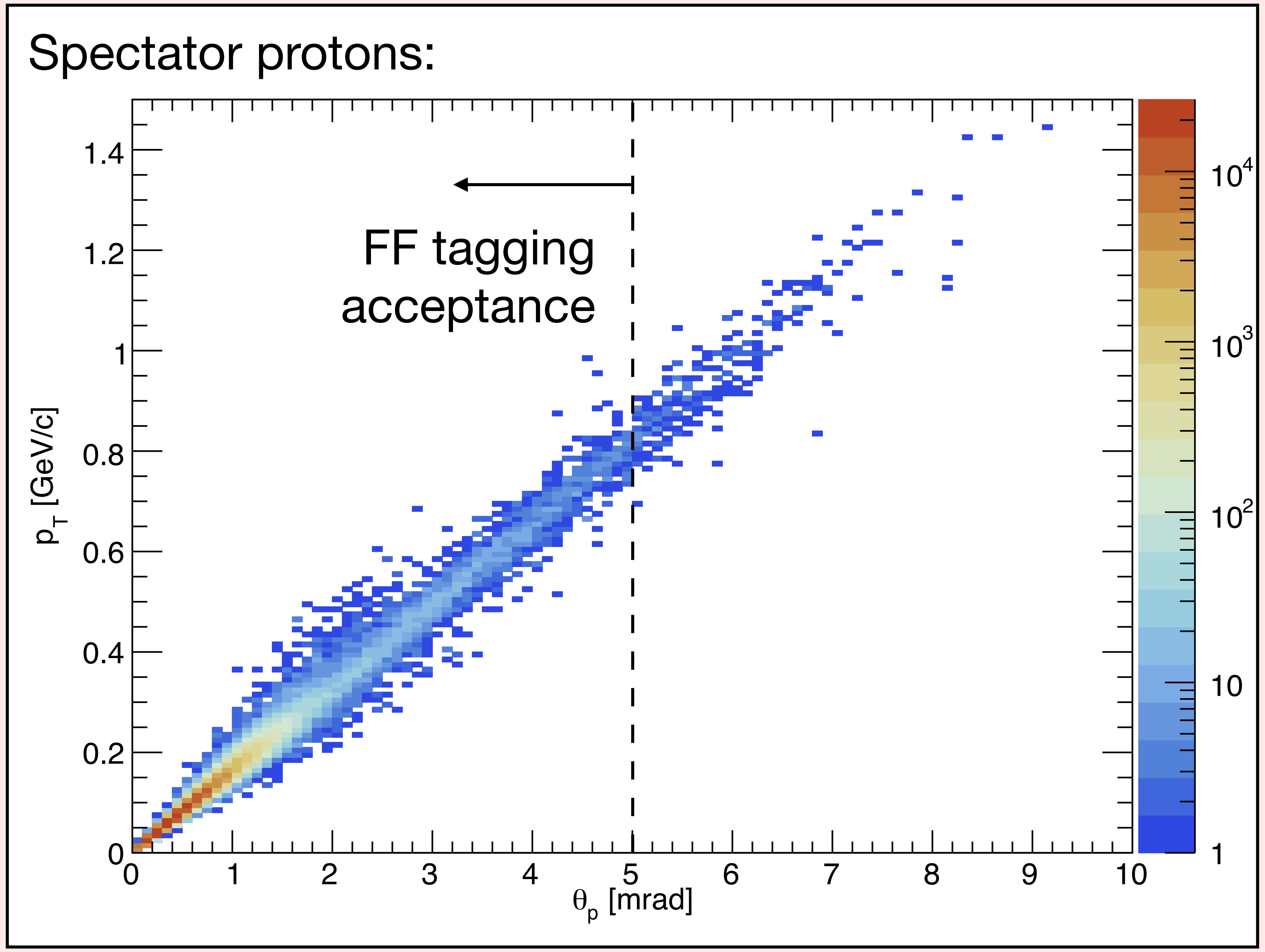
Note: the eA luminosity is per nucleon

A_1^n from e^3He DIS:

- Can be extracted from $A_1^{^3\mathrm{He}} = P_n \frac{F_2^n}{F_2^{^3\mathrm{He}}} A_1^n + 2P_p \frac{F_2^p}{F_2^{^3\mathrm{He}}} A_1^p$

- Or **directly** measured double spectator tagging:





* EPIC 25.05.00 Sim.

$0.01 < y < 0.95$

$Q^2 \geq 2,\ W^2 \geq 4$

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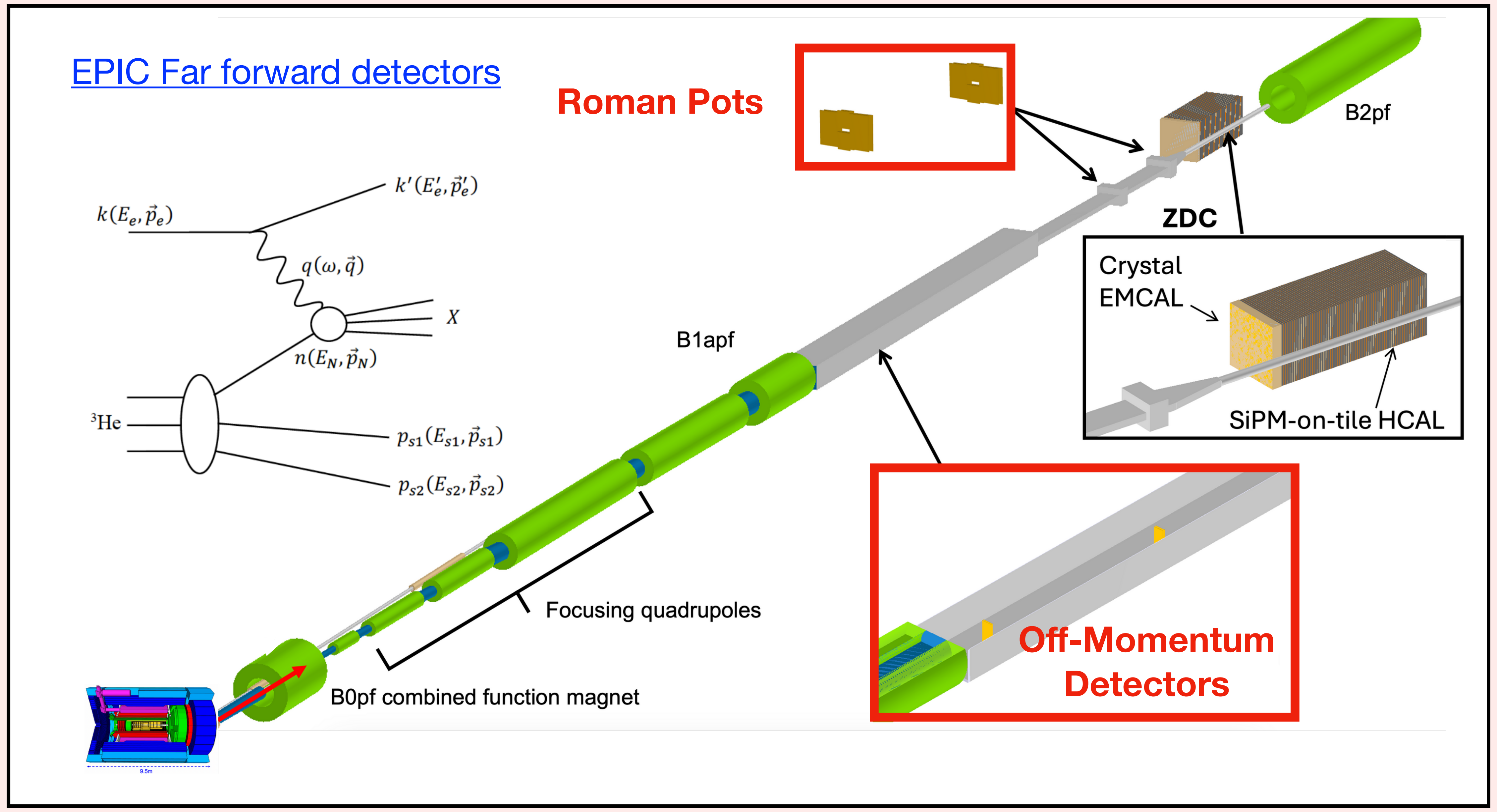

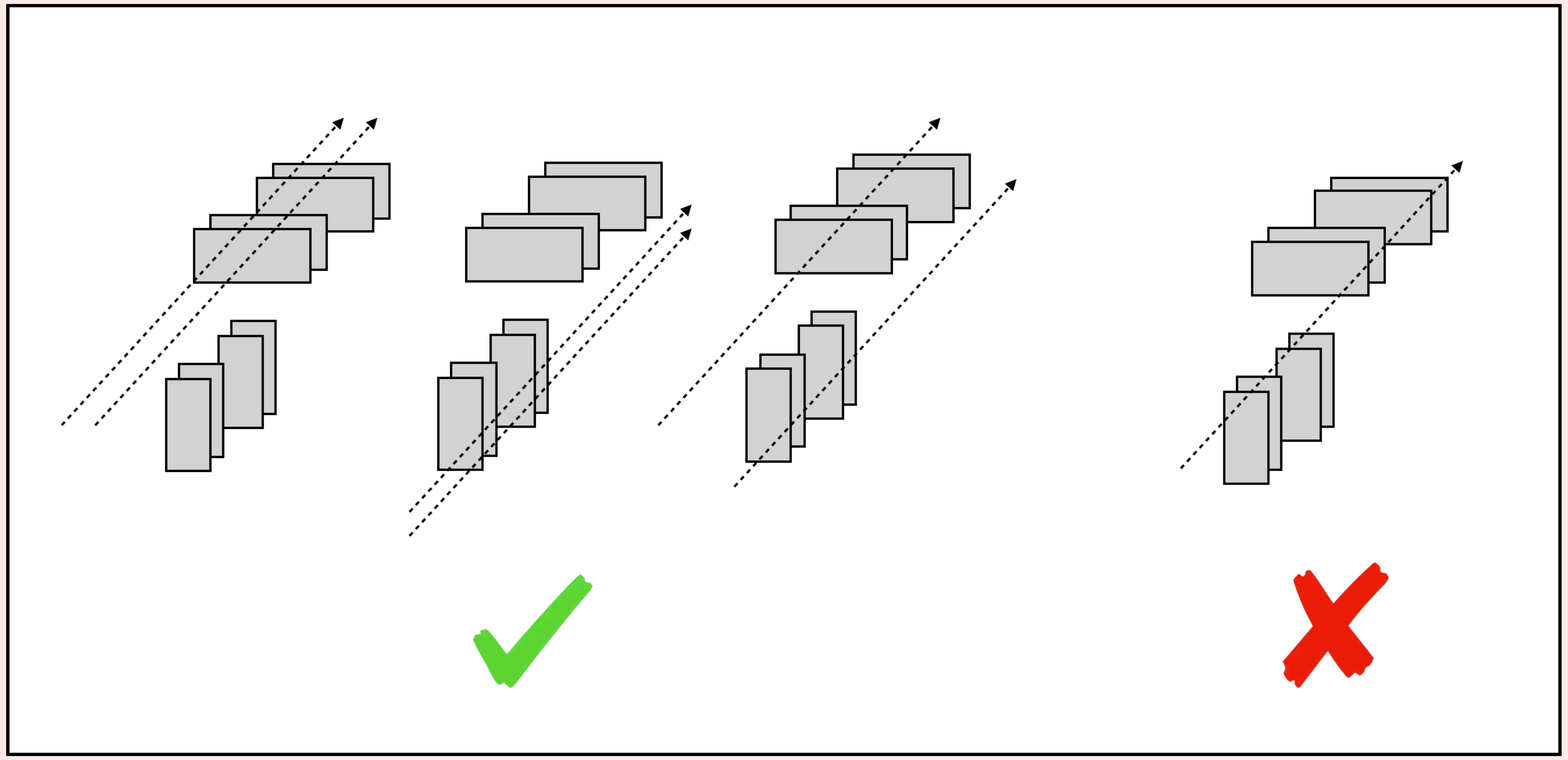

- Currently a simple tracking algorithm based on hit per plane is used

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

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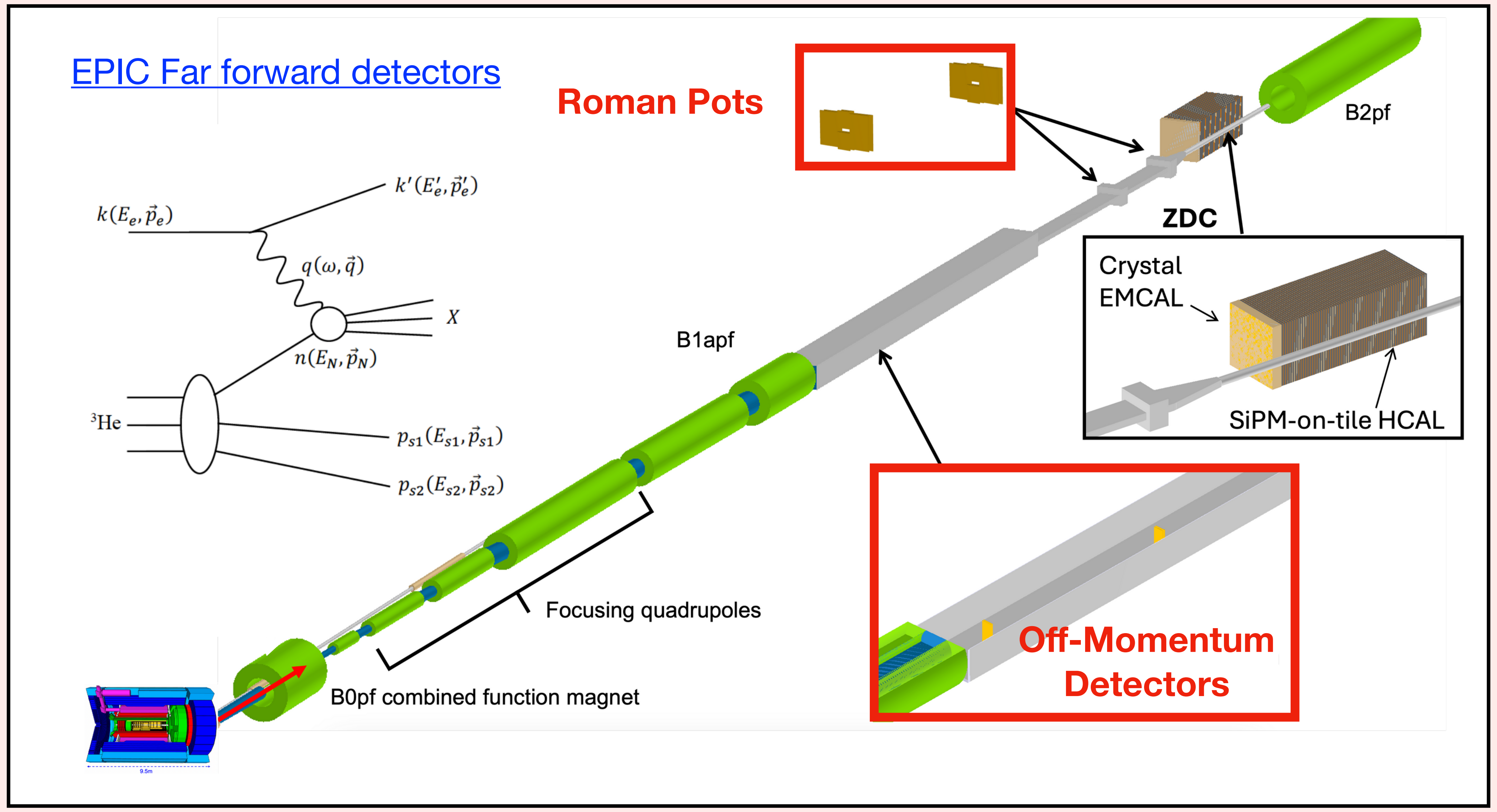

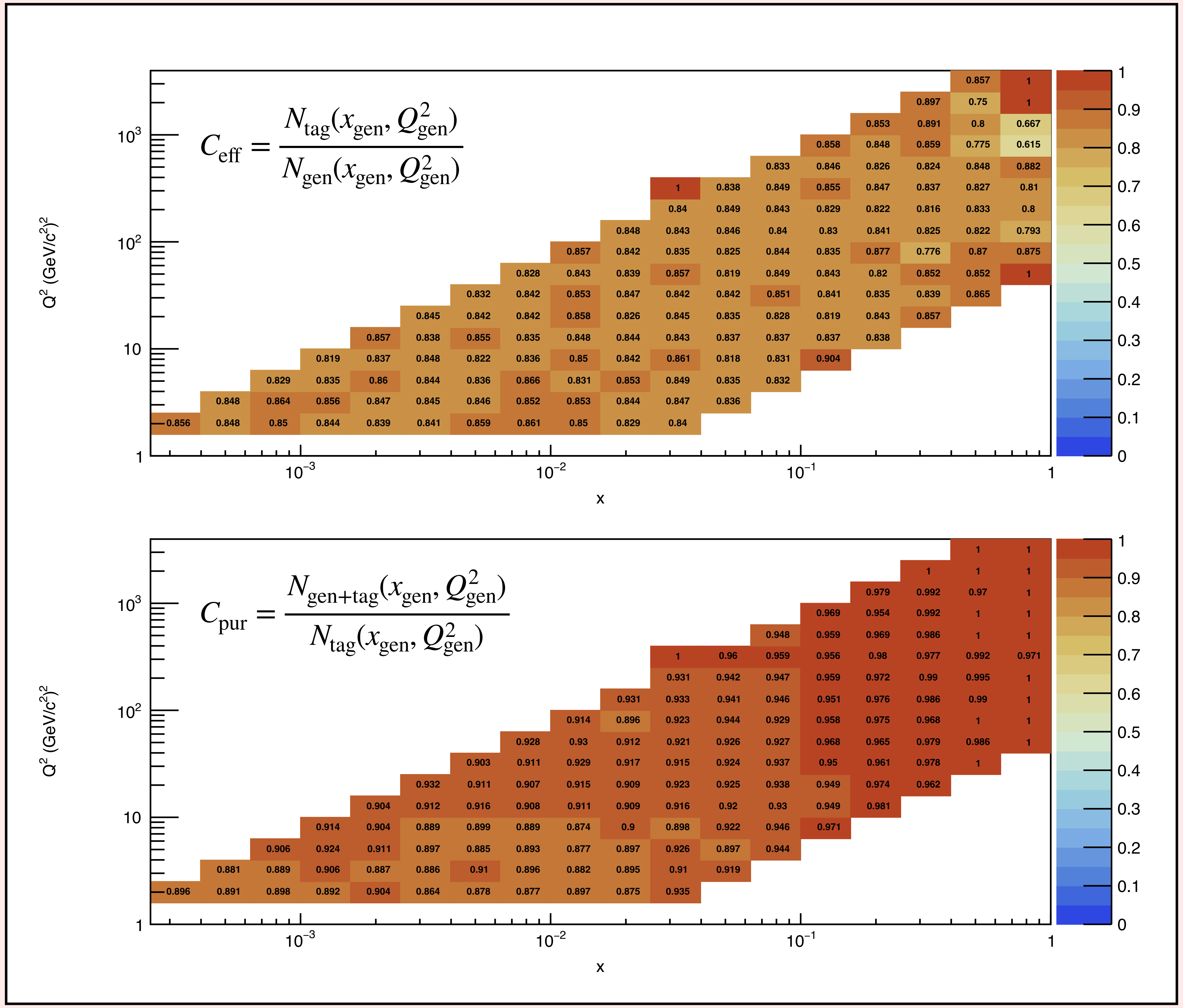

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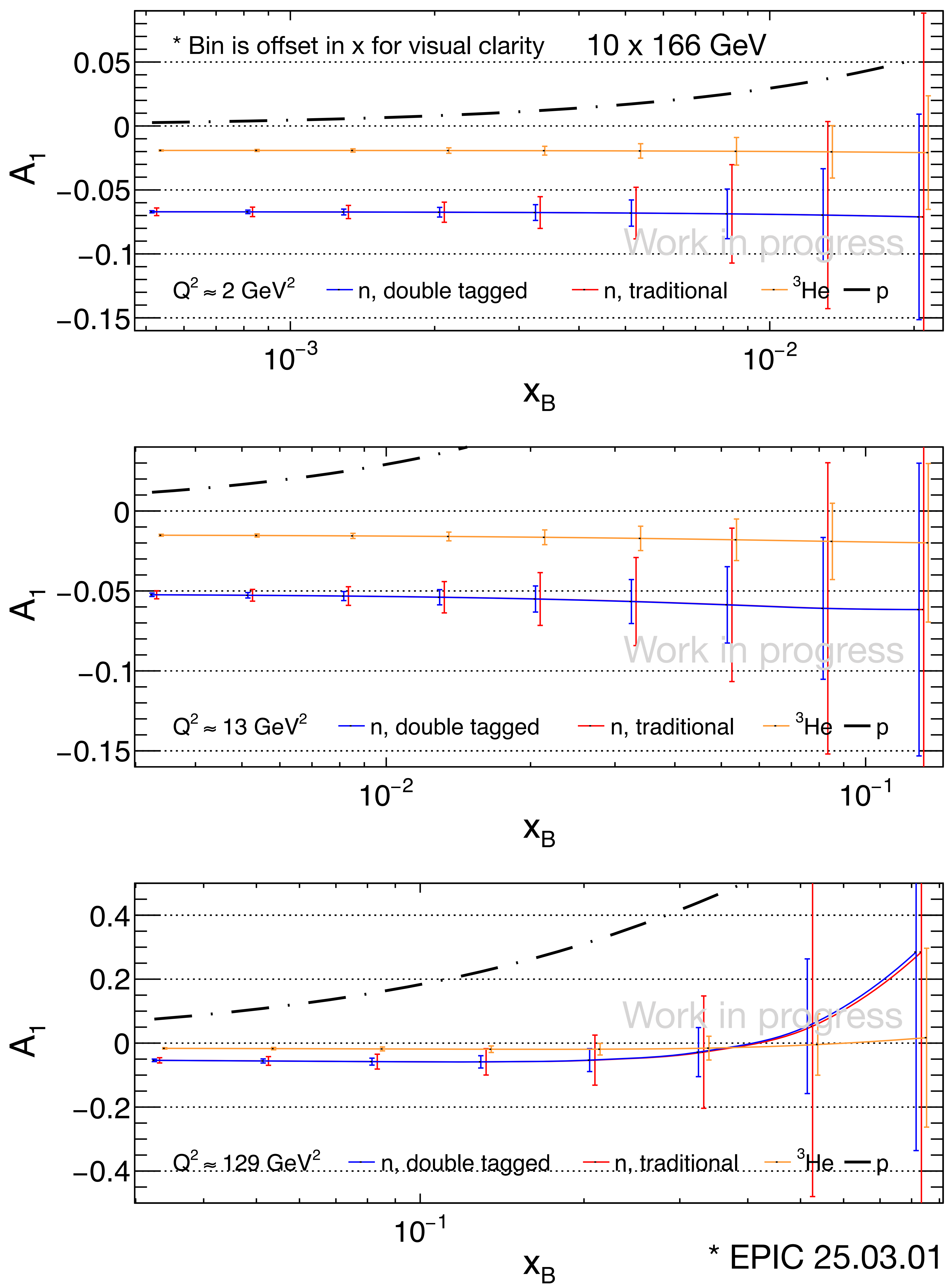

* EPIC 25.03.01 Sim.

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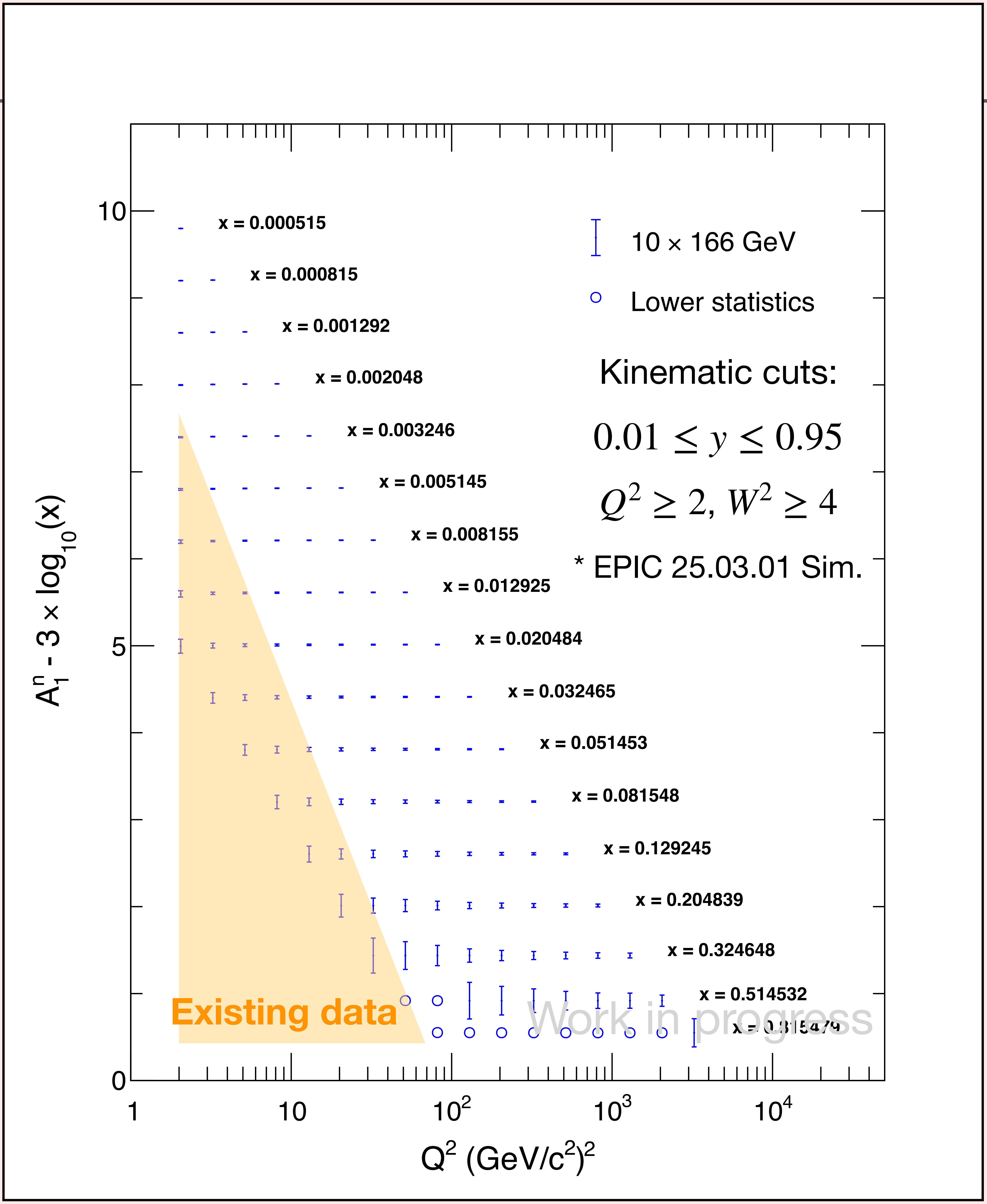

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g_1^p and g_1^n

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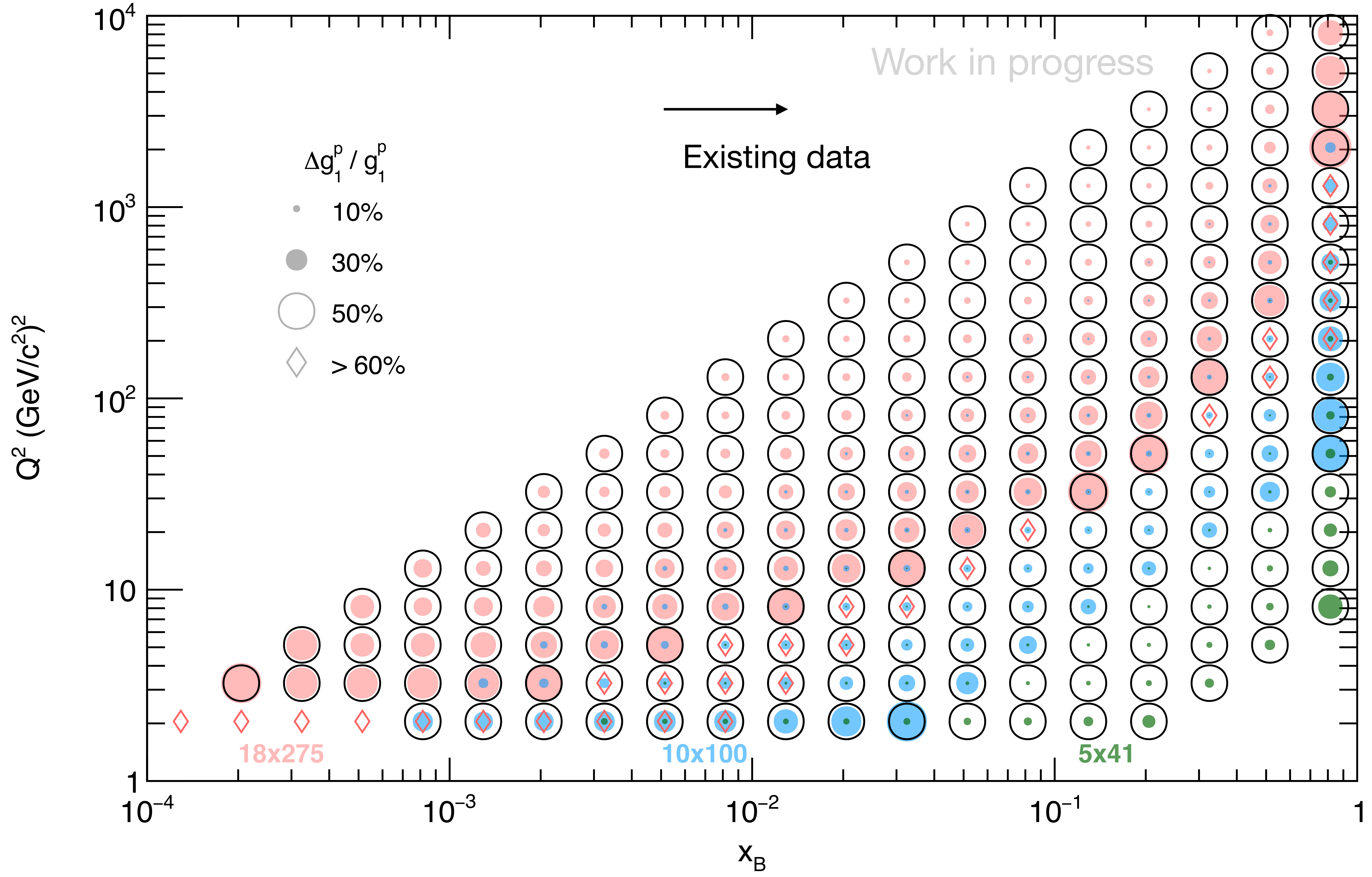
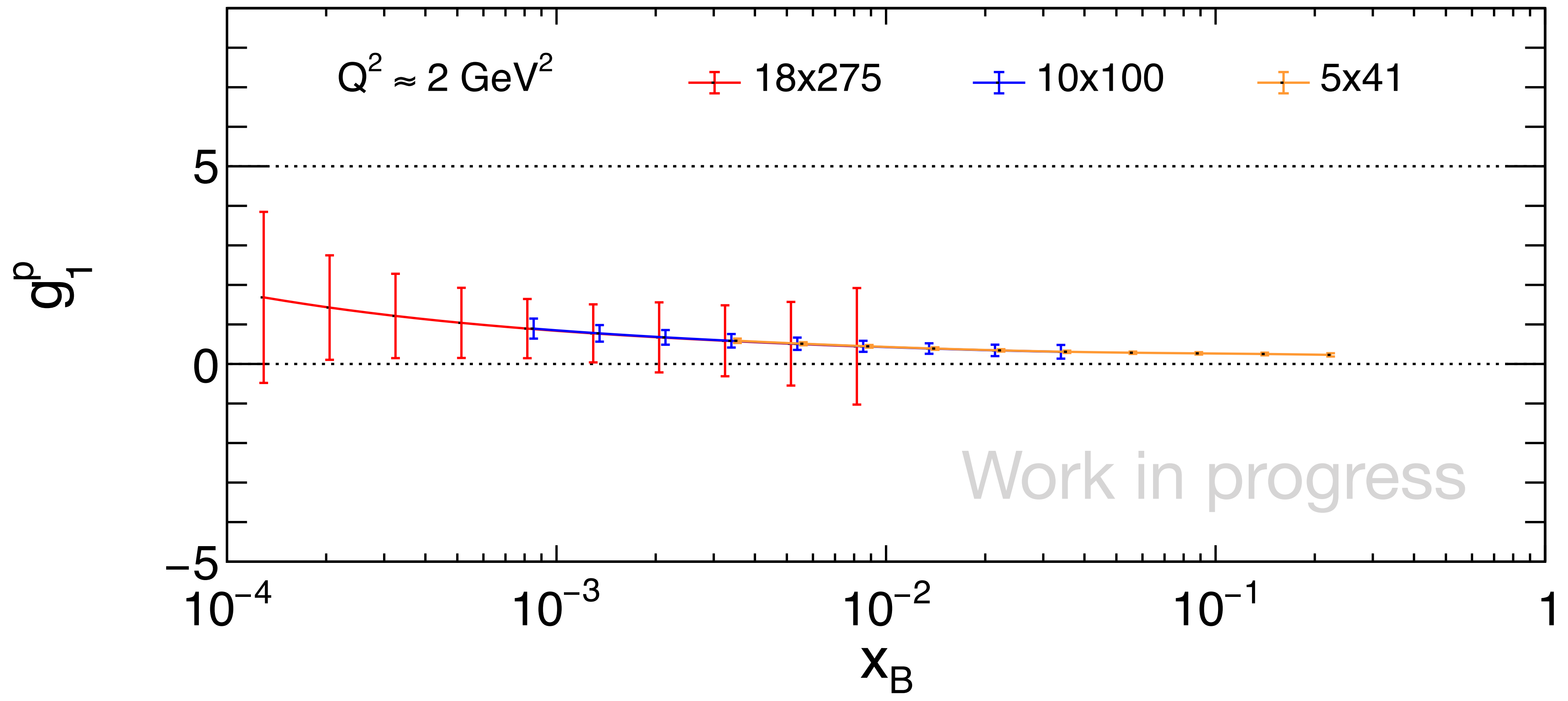
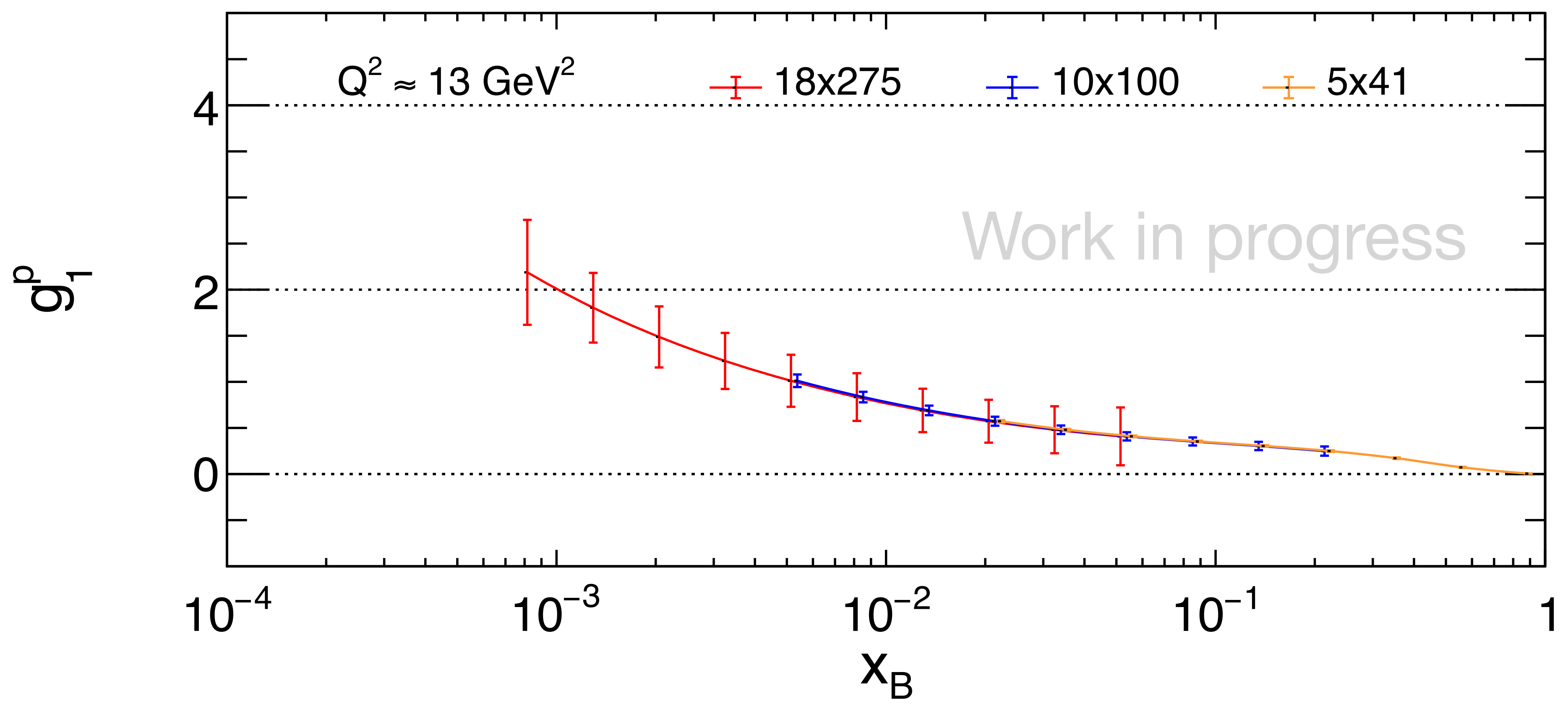
* EPIC 24.06.0 Sim.







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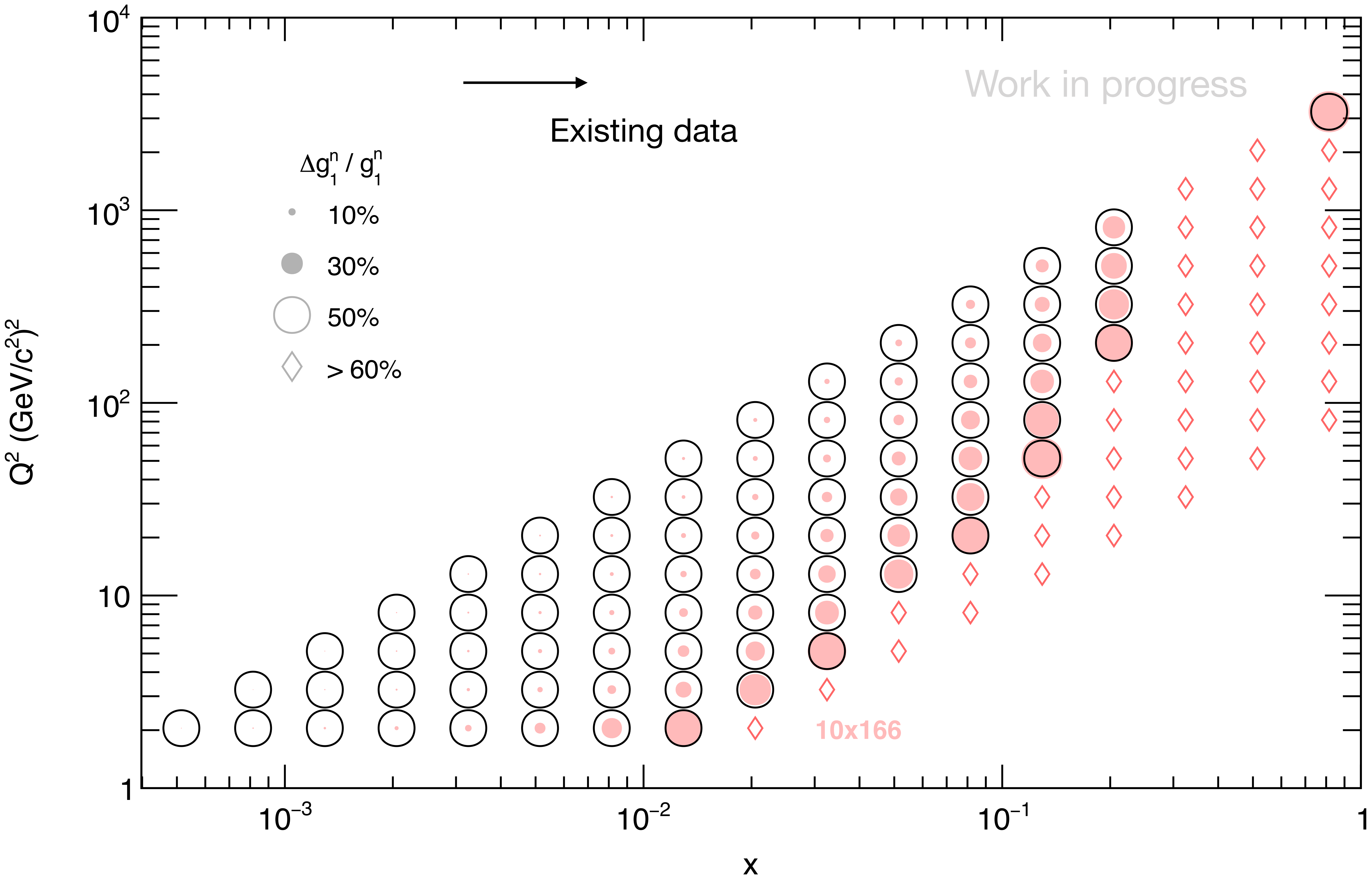

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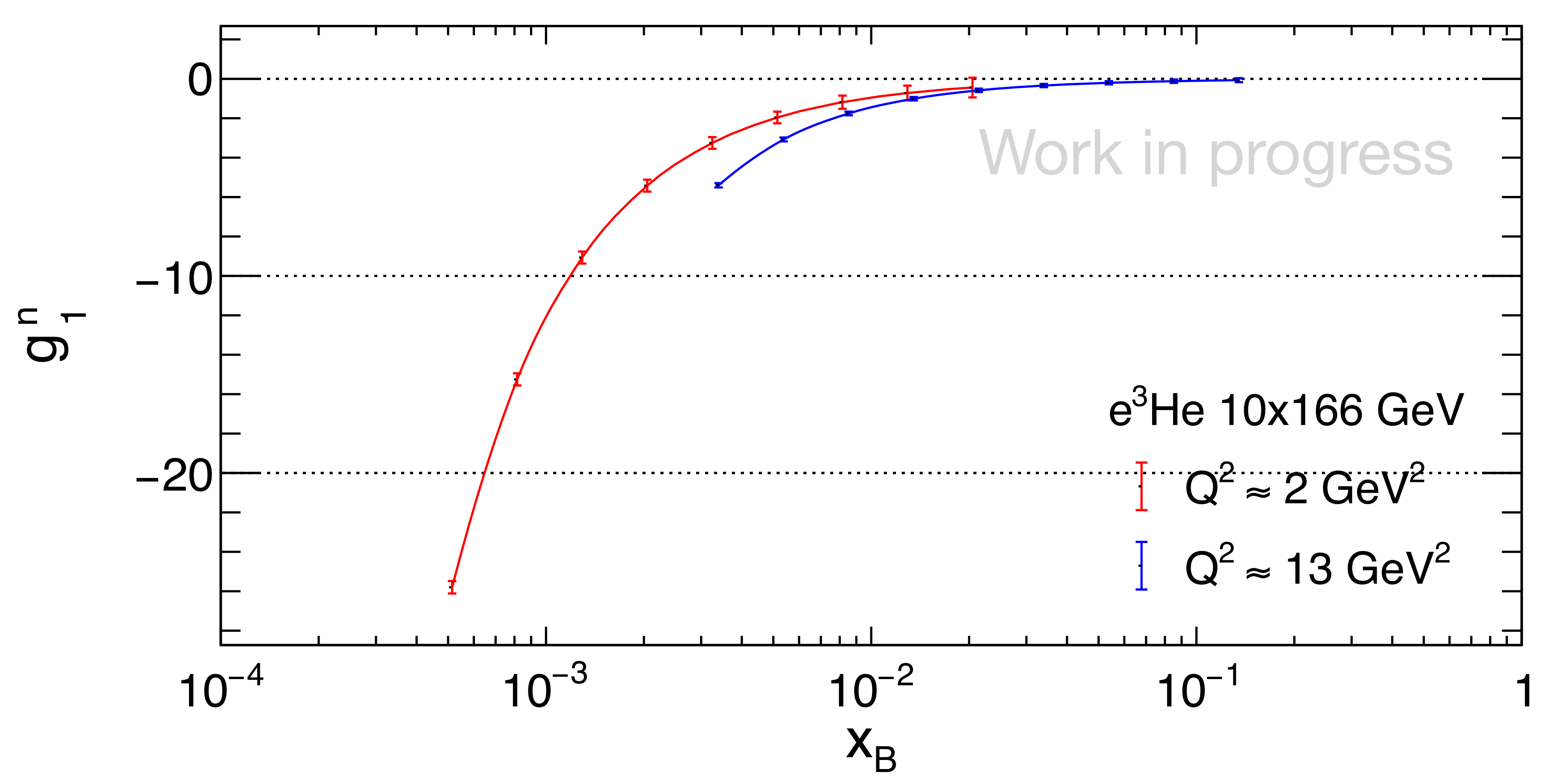


What’s new?

Inclusive electron reconstruction

Current available reconstruction in EICRecon

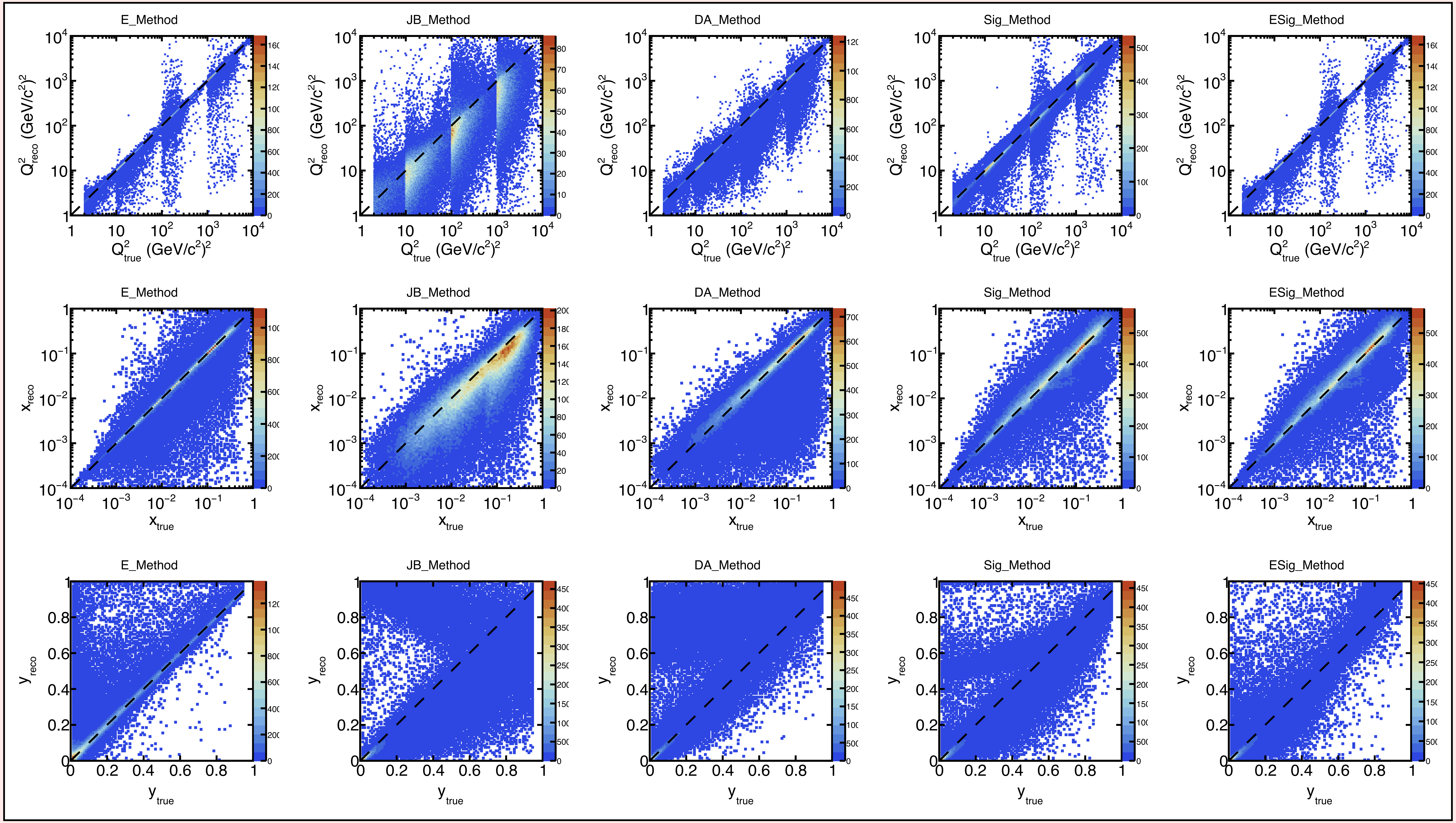
Algorithm	Q^2	Inelastic y	Bjorken x
Electron (E)	$2E_0E_e(1+\cos\theta_e)$	$1-\frac{E_e(1-\cos\theta_e)}{2E_0}$	$\frac{Q^2}{4E_0E_ey}$
Jacquet-Blonde (JB)	$\frac{p_{t,h}^2}{1-y}$	$\frac{\delta_h}{2E_0}$	
Double-Angle (DA)	$\frac{4E_0^2}{\tan(\frac{\theta_e}{2})(\tan(\frac{\theta_e}{2})+\delta_h/p_{t,h})}$	$\frac{\delta_h/p_{t,h}}{\tan(\frac{\theta_e}{2})+\delta_h/p_{t,h}}$	
Sigma (Σ)	$\frac{E_e^2\sin^2\theta_e}{1-y}$	$\frac{\delta_h}{\delta_h+E_e(1-\cos\theta_e)}$	
E-Sigma ($e\Sigma$)	Q_E^2	$\frac{Q_E^2}{4E_0E_ex_\Sigma}$	x_Σ

$$p_{t,h}^2 = (\sum_h p_{x,h})^2 + (\sum_h p_{y,h})^2 \qquad \delta_h = \sum_h E_h - p_{z,h}$$

- Electron Finder Library
- MC info to pair track and cluster
- TruthID (associate hit to MC) for eID
- Assume first MC outgoing electron is the scattering electron

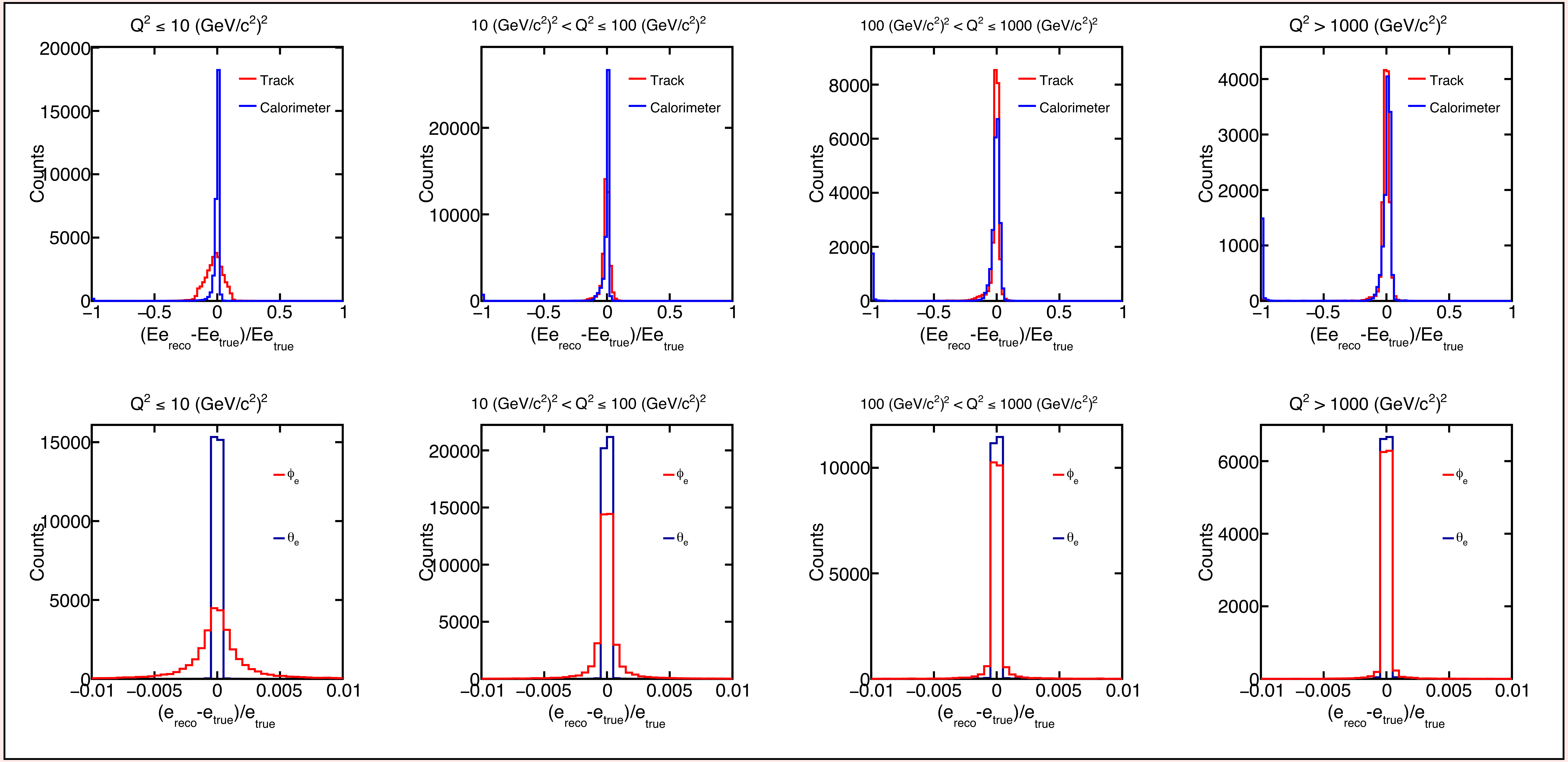
Electron Reconstruction (Truth ID)

* EPIC 24.03.1 Sim. ep 18x278 GeV



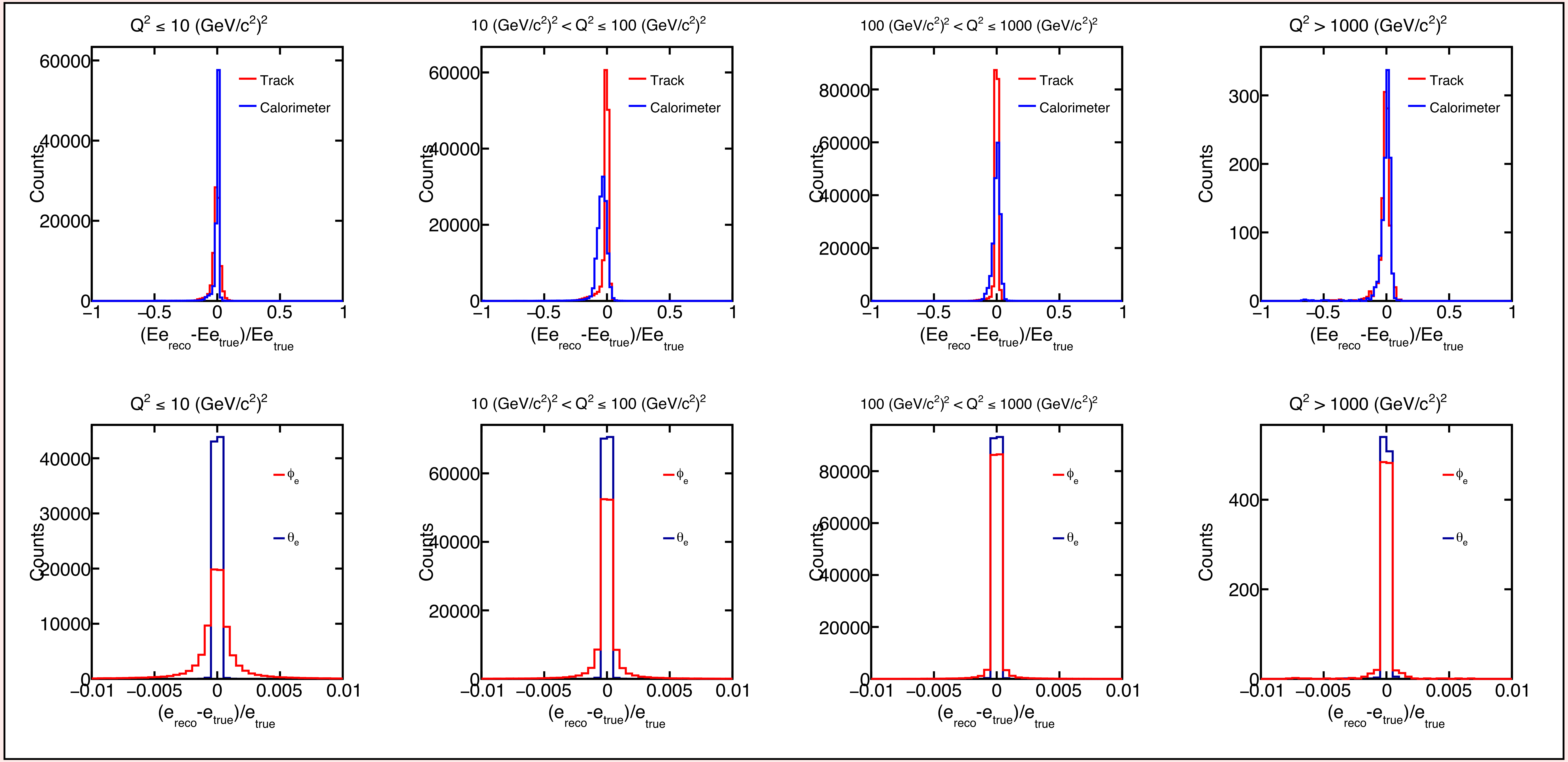
Energy from tracks vs from clusters (ep)

* EPIC 24.03.1 Sim. ep 18x278 GeV



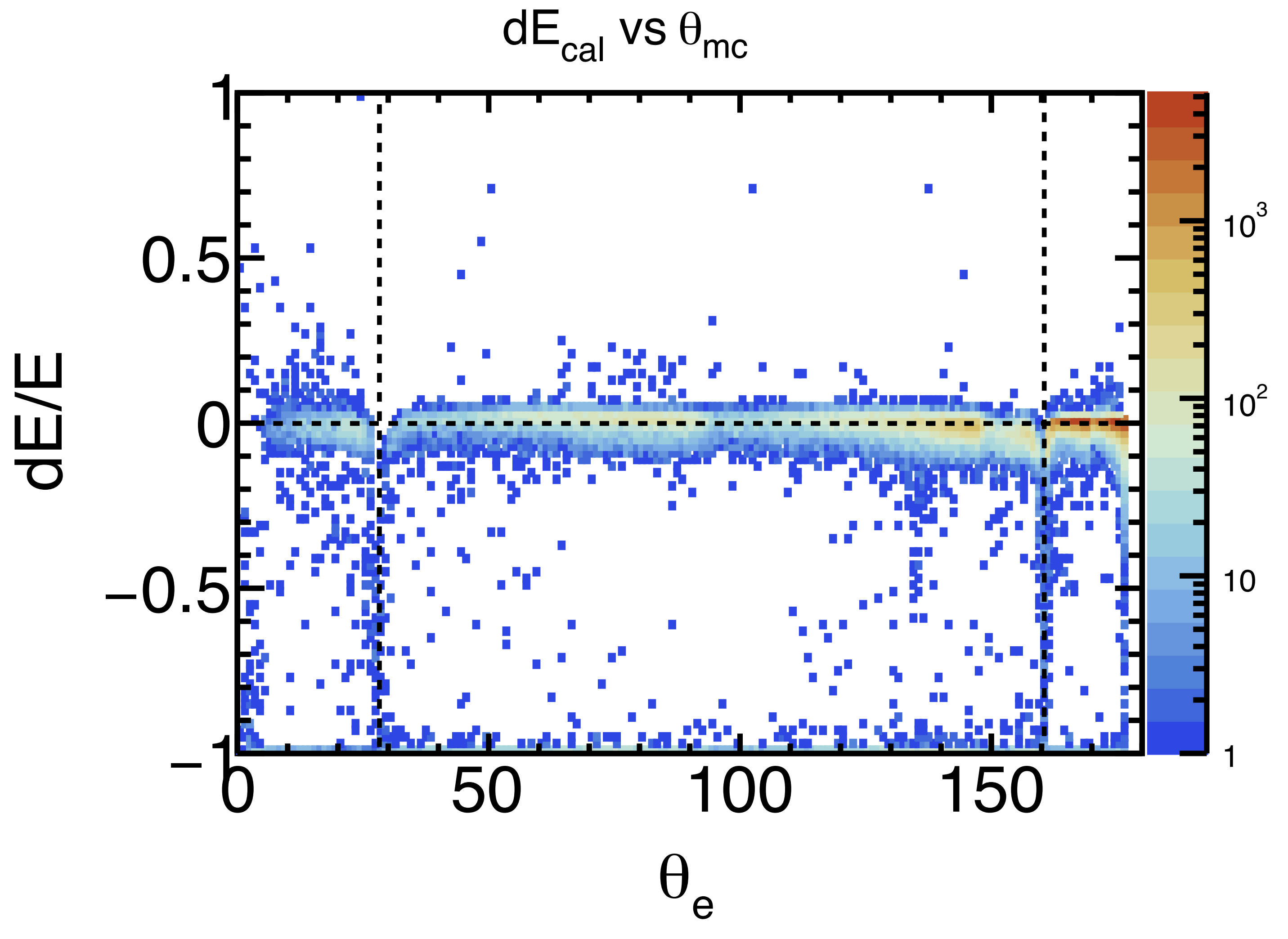
Energy from tracks vs from clusters (en)

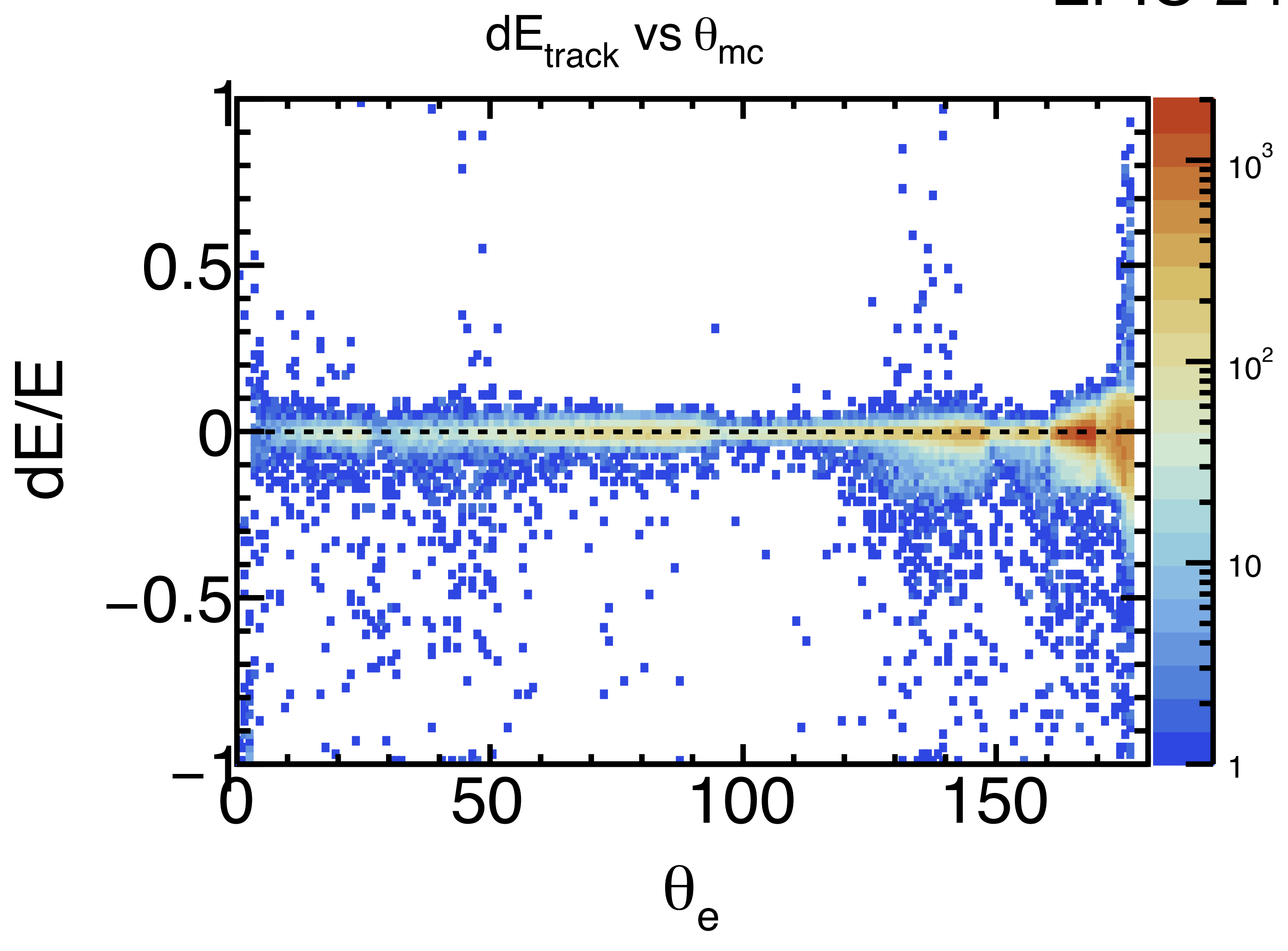
* EPIC 25.05.0 Sim. eHe3 10x166 GeV

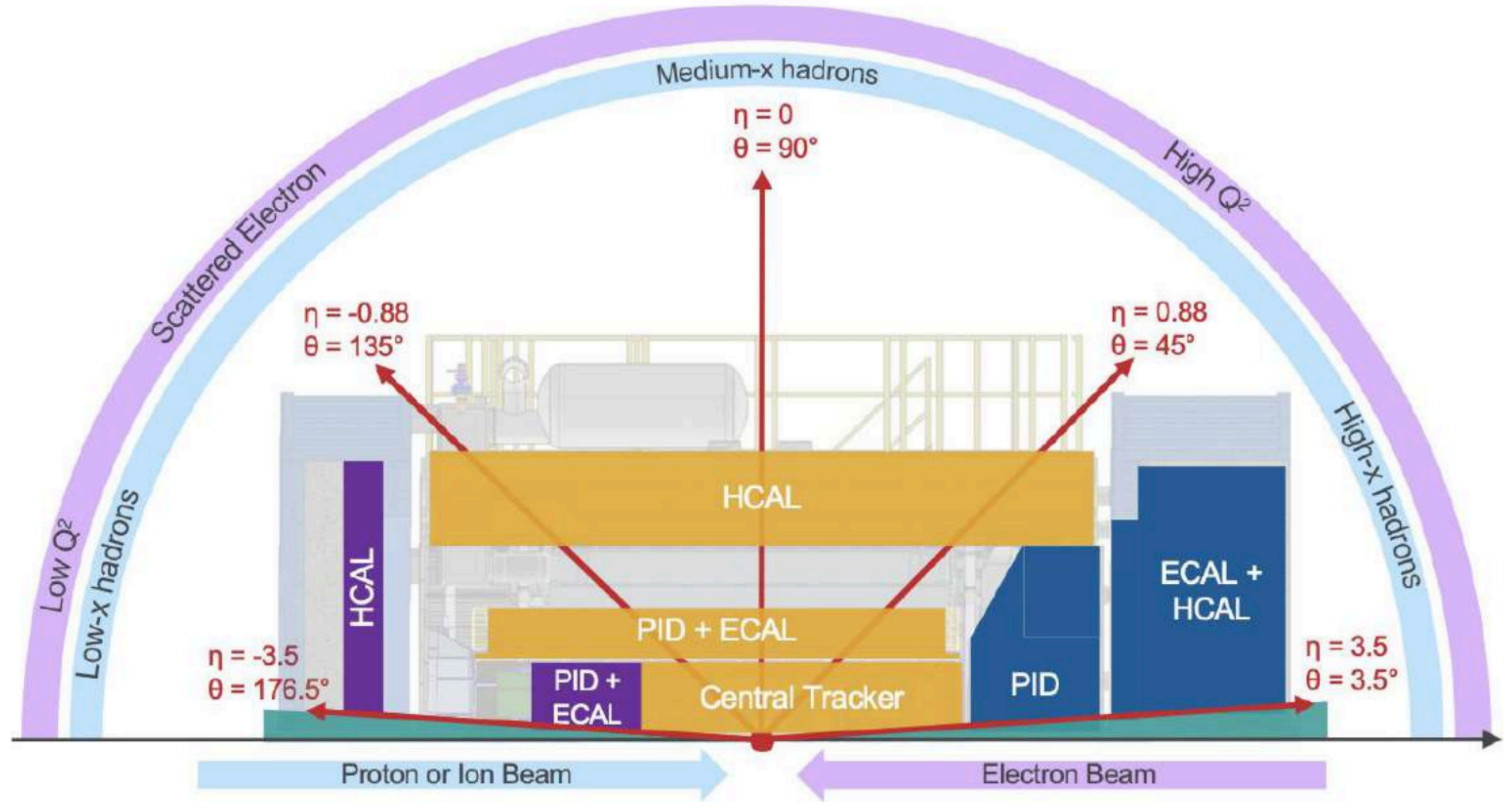


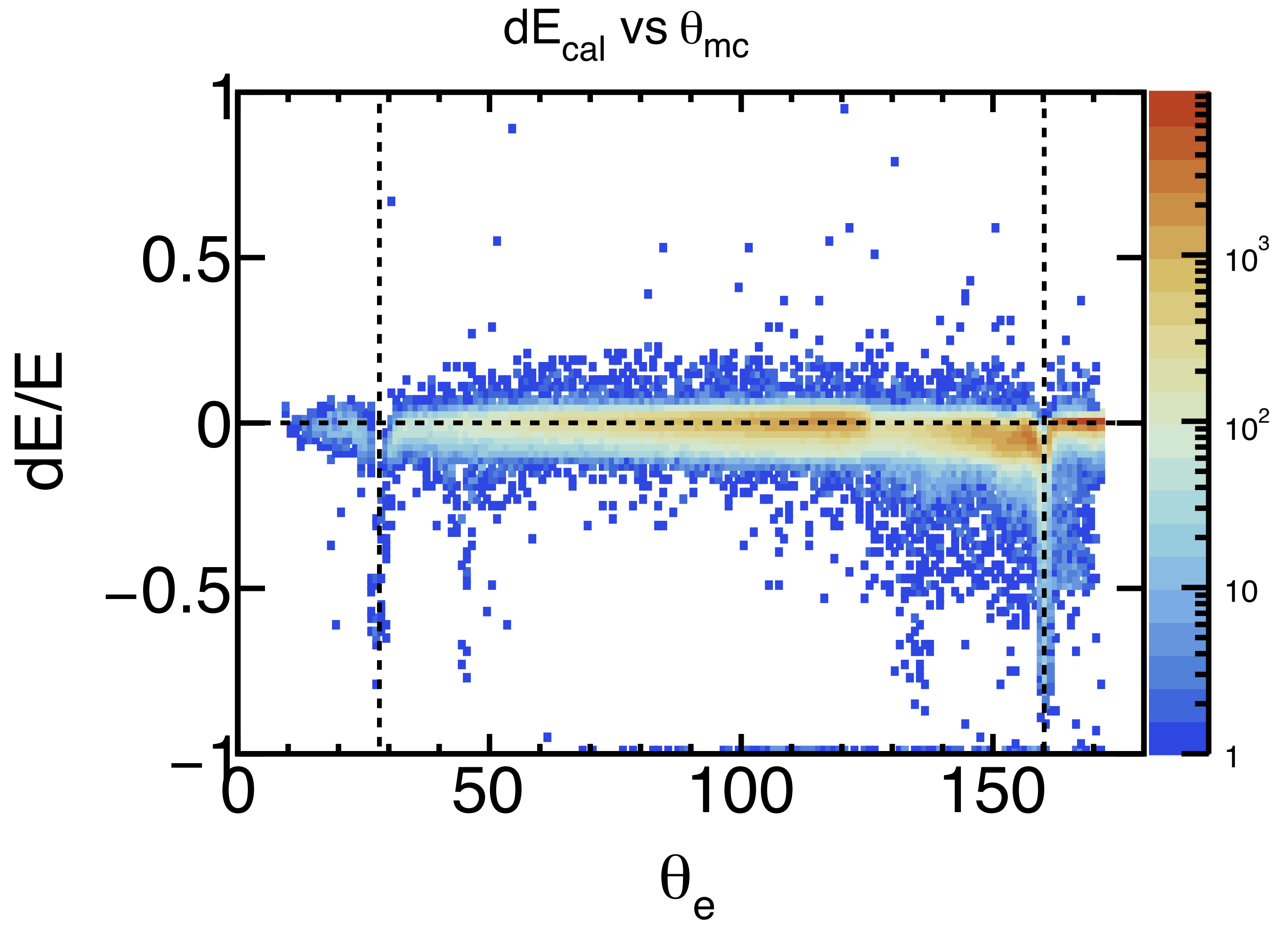
Energy and Track Resolution

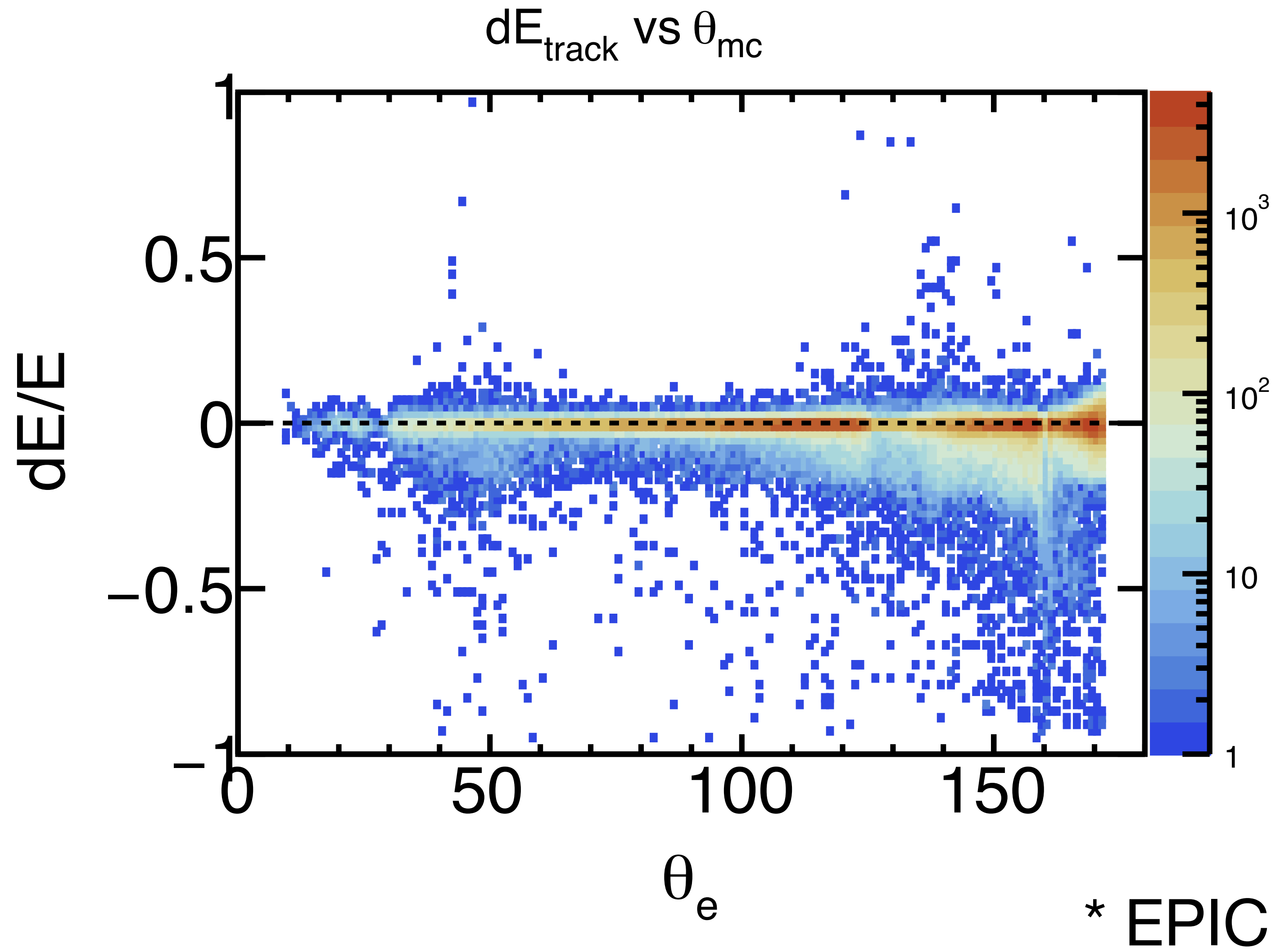
* EPIC 24.05.0 Sim. ep 18x278 GeV











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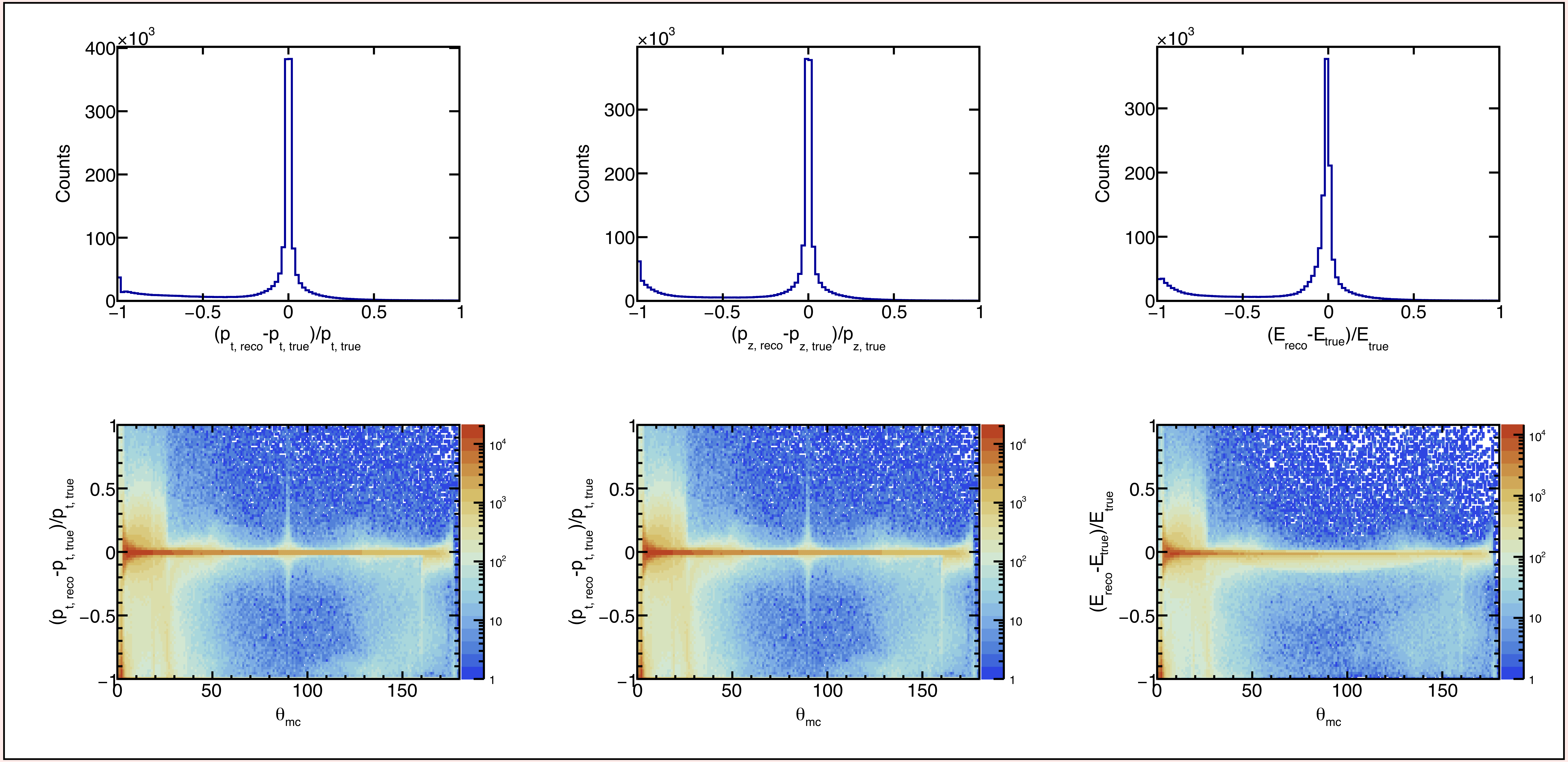
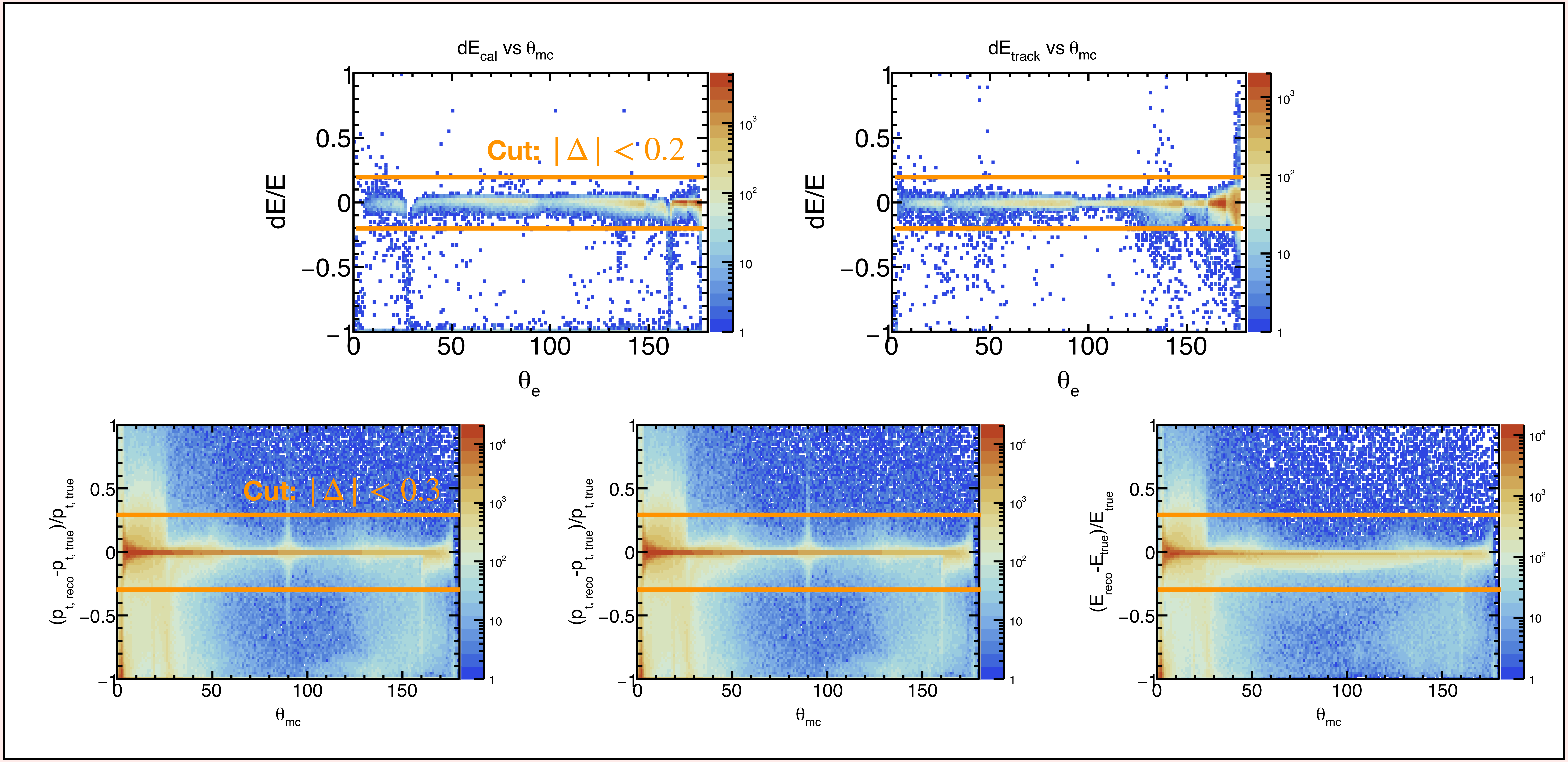
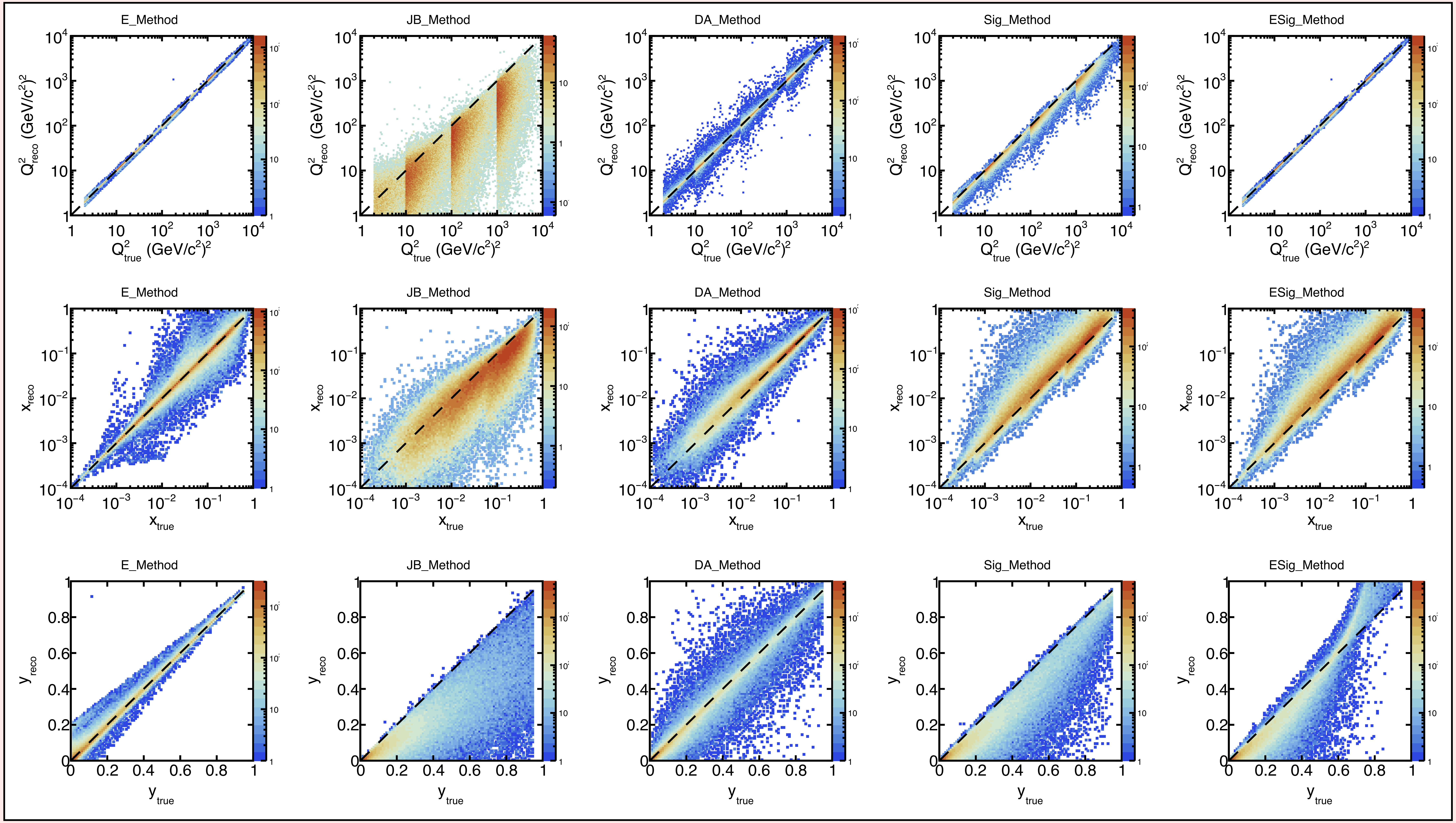
HFS reconstruction



Apply QA cuts

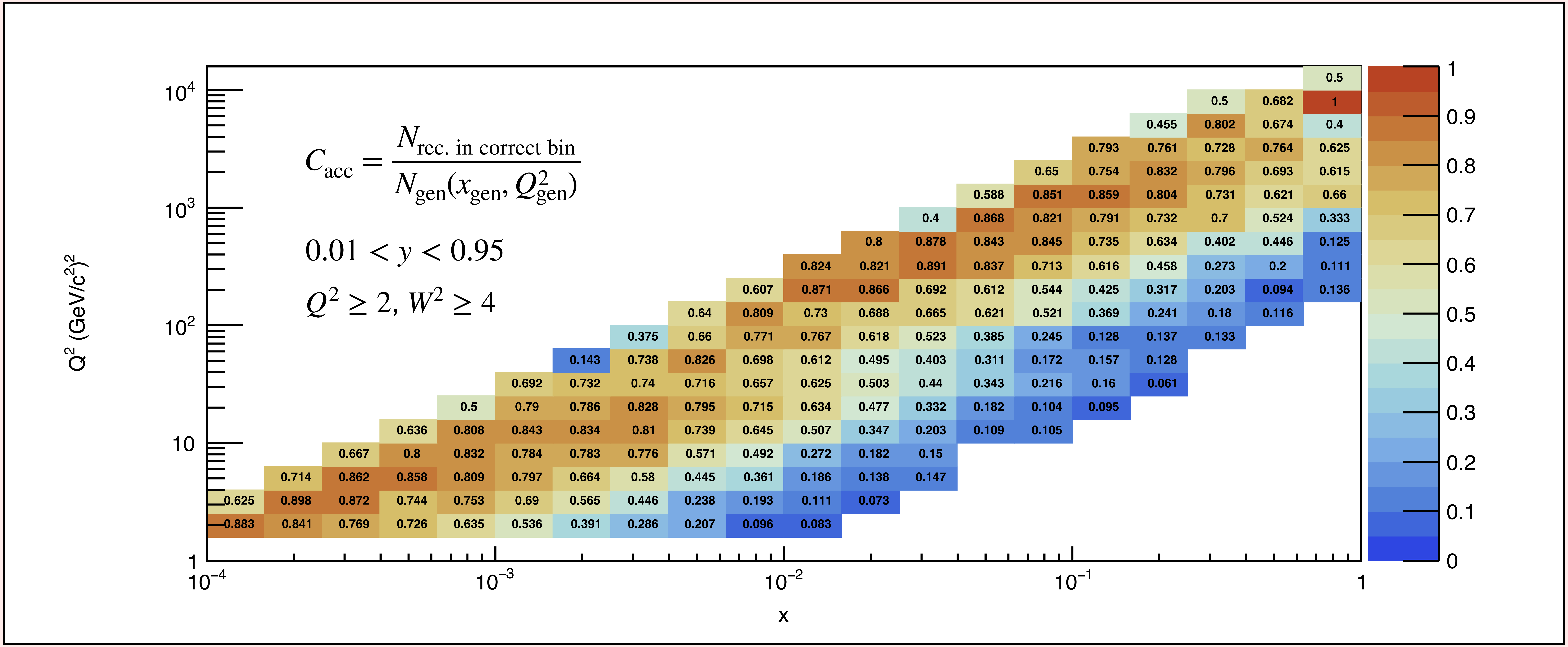


Electron Reconstruction (Truth ID) - after cuts



Select eRecon method

Electron Method Bin Efficiency



Select eRecon method

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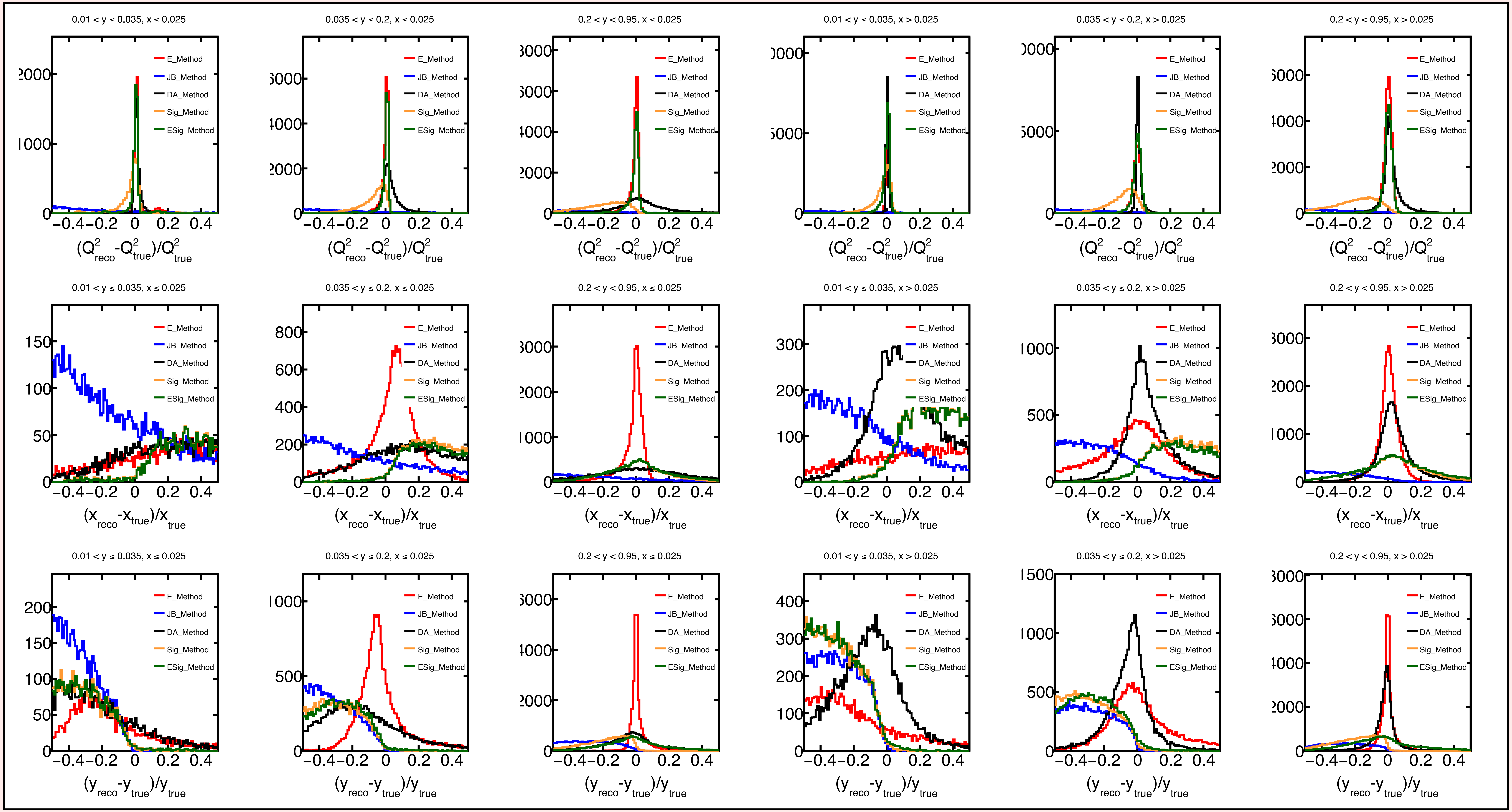

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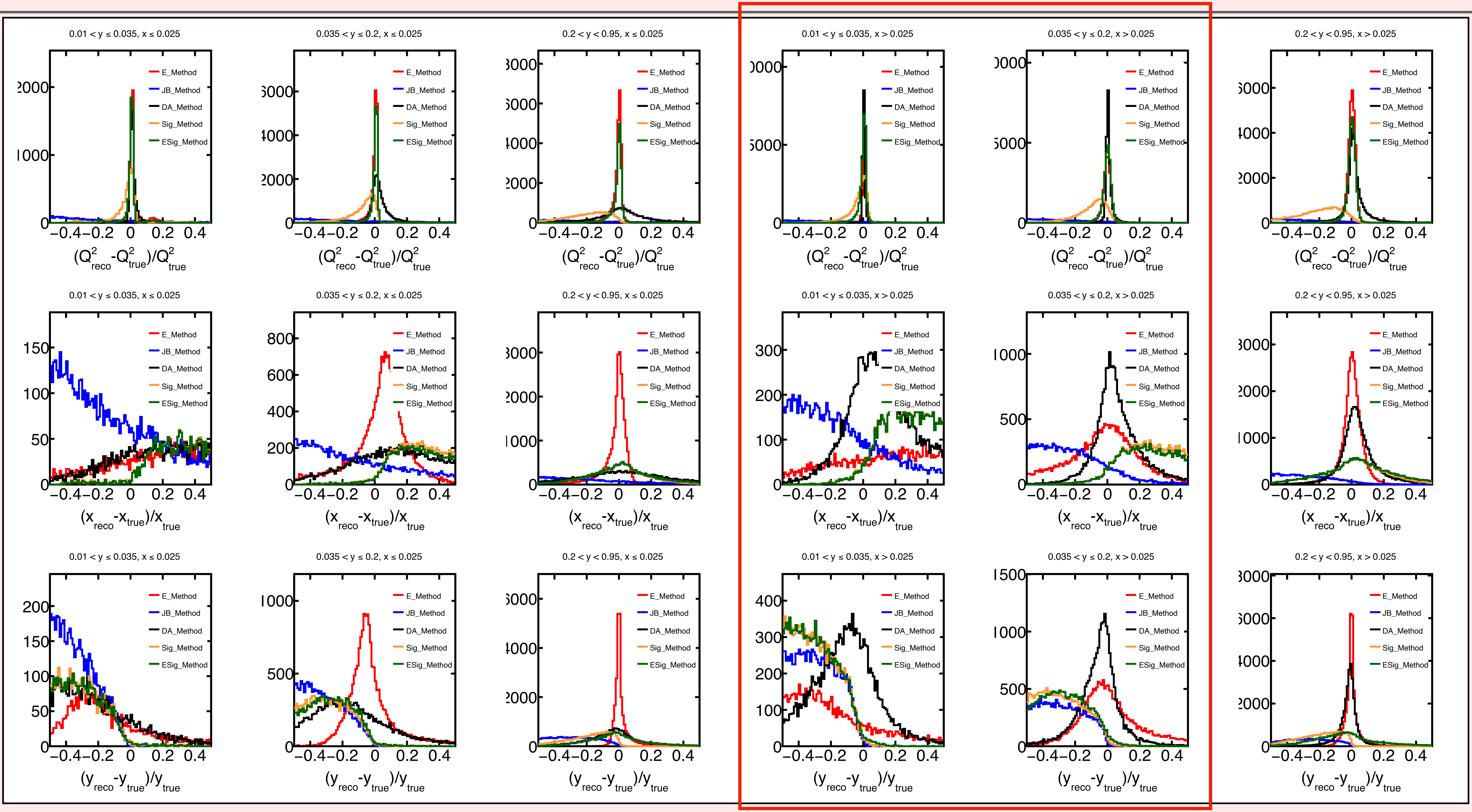
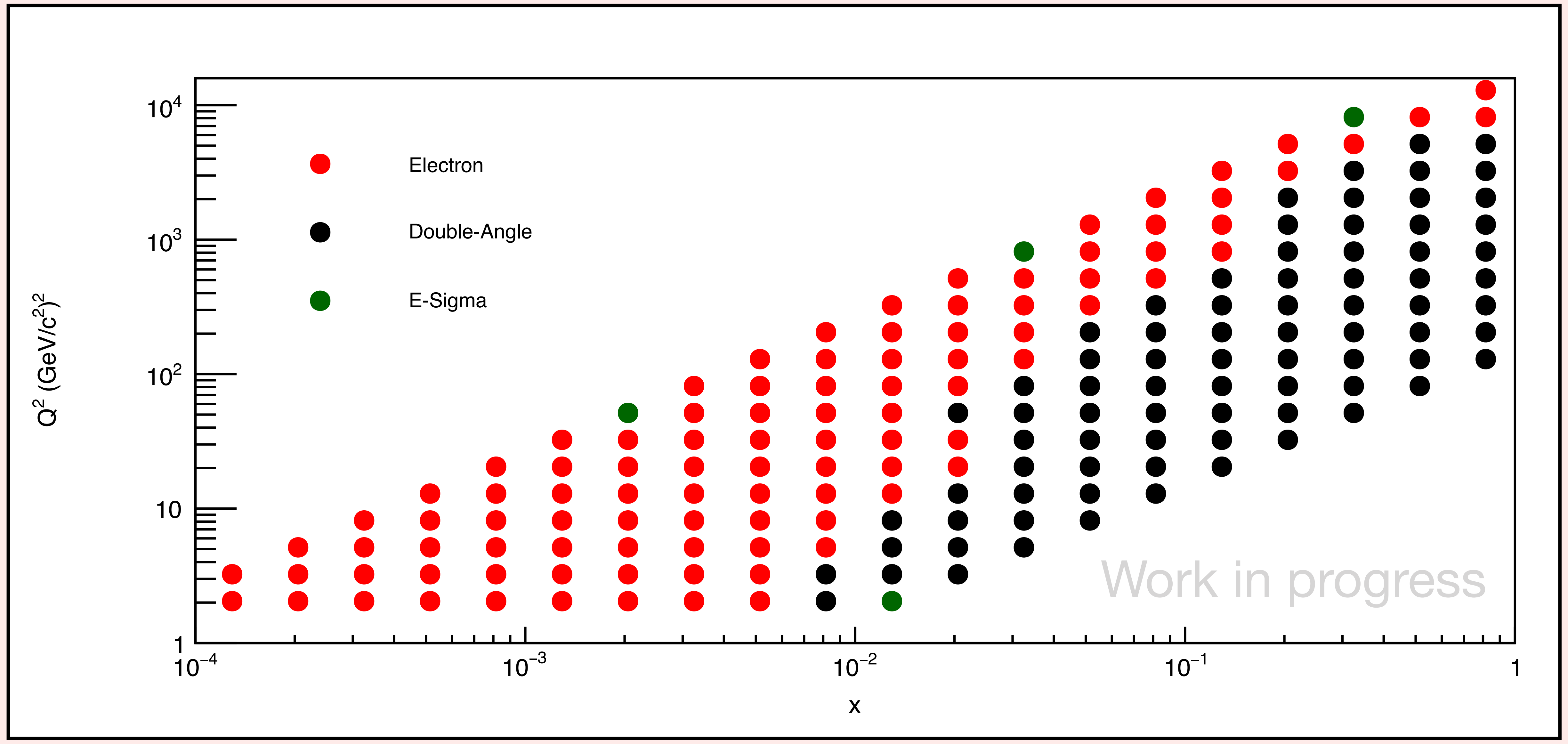
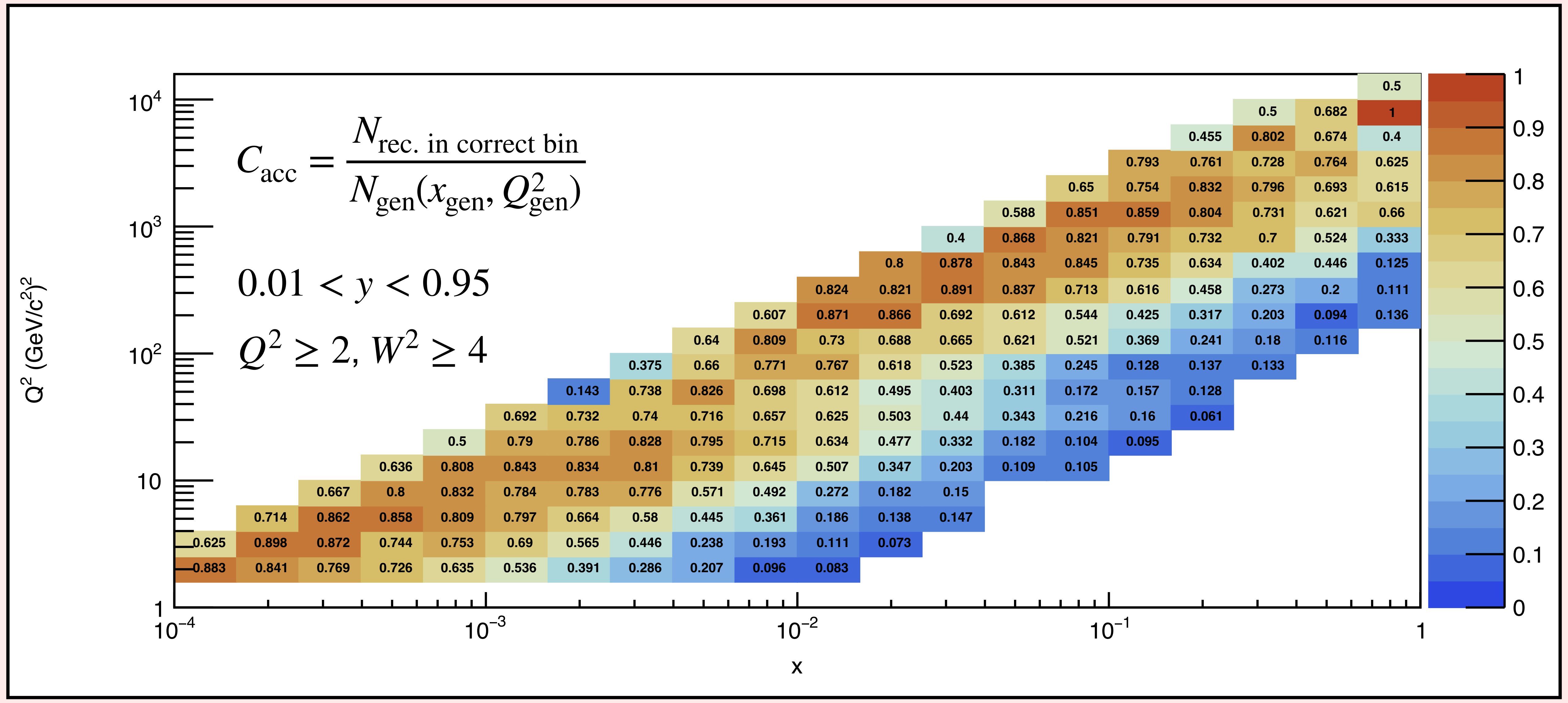
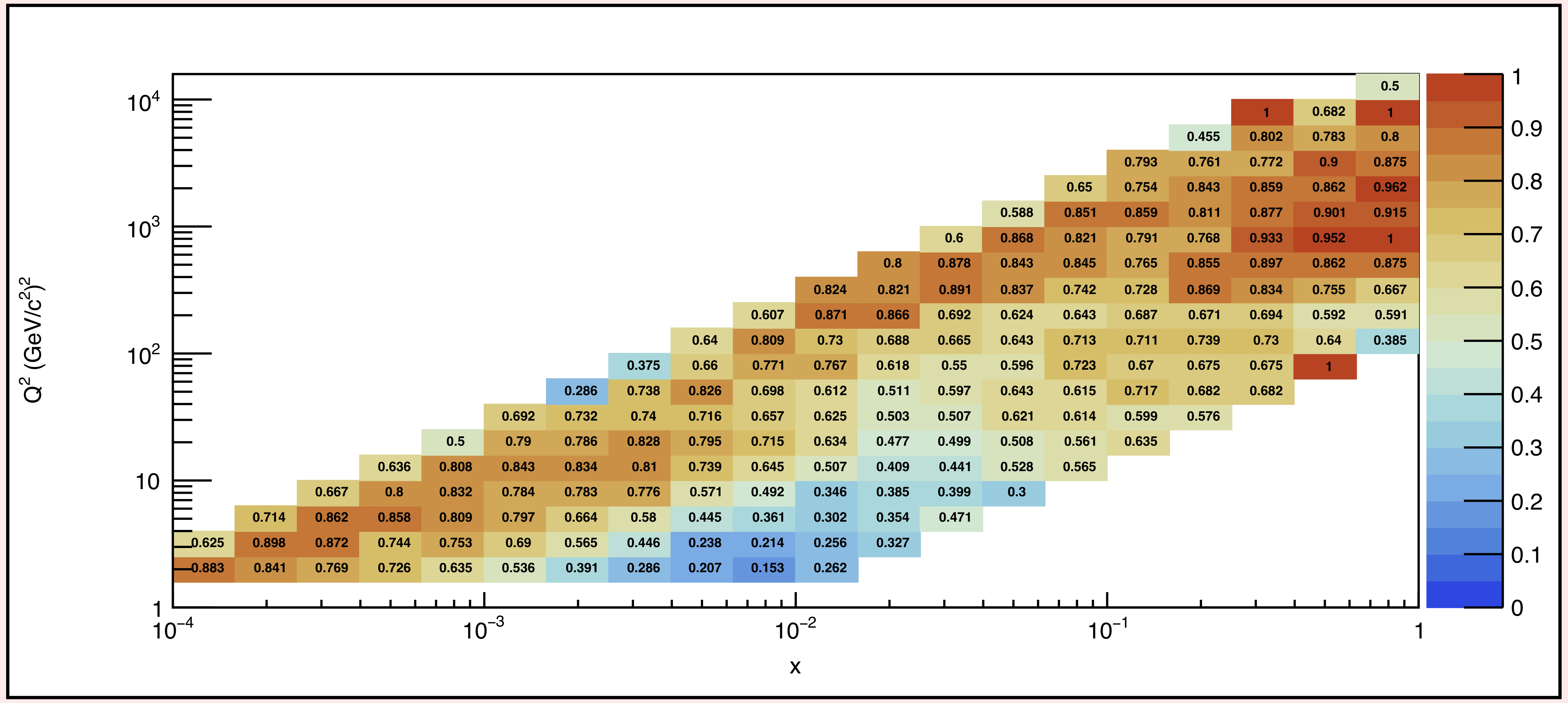


Select eRecon method

<u>Recon. Method Lookup Table</u>







QA List

Example list of variables/quantities for PWG to follow

Kinematic reconstructions	quantity	Reco	Truth	Response (2D)	Purity/bin migration	detector acceptance-only corrected	Unfolding/full correction
(electron,JB, DA,sigma, e-sigma)	Q2	yes	yes	yes	optional	good to have	optional
	x	yes	yes	yes	optional	good to have	optional
	y	yes	yes	yes	optional	good to have	optional
	dQ2/Q2						
	dx/x						
	dy/y						
	e' energy	yes	yes	yes	optional	optional	
	e' theta	yes	yes	yes	optional	optional	
	HFS (E-pz)	yes	yes	yes	optional	optional	
	HFS (pT)	yes	yes	yes	optional	optional	
Event level							
	E-pz (e'+HFS)	yes	yes	yes	optional	optional	
	E/p for calorimeter	yes	yes	yes	optional	optional	
	Calo clusters	yes	no	no			
Observable of interest							
	e.g., t, etc.	yes	yes	yes	yes	yes	optional
Detector specific variables	Depends						
PID quantities:	add when it comes						

This list is not and should not be frozen but a living document for analyzers. And this should be adapted to each analysis and experts (conveners, ACs) can request to add things to check

QA List

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Analysis Note:
Projection on A_1^n and g_1^n Measurement at
ePIC in the Early Running of EIC

W. Lin[1, 2]

Stony Brook

Stony Brook

Contents

Analysis details and eHe3 QA plots will all be in note

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https://doi.org/10.1016/j.nima.2023.168563

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Next step?

- Refine electron kinematic reconstruction
- Weight data for polarized DIS?

$$1 + \lambda D(y)\frac{\Delta \otimes D^{q,g\to h}}{F^h_{UU}}$$

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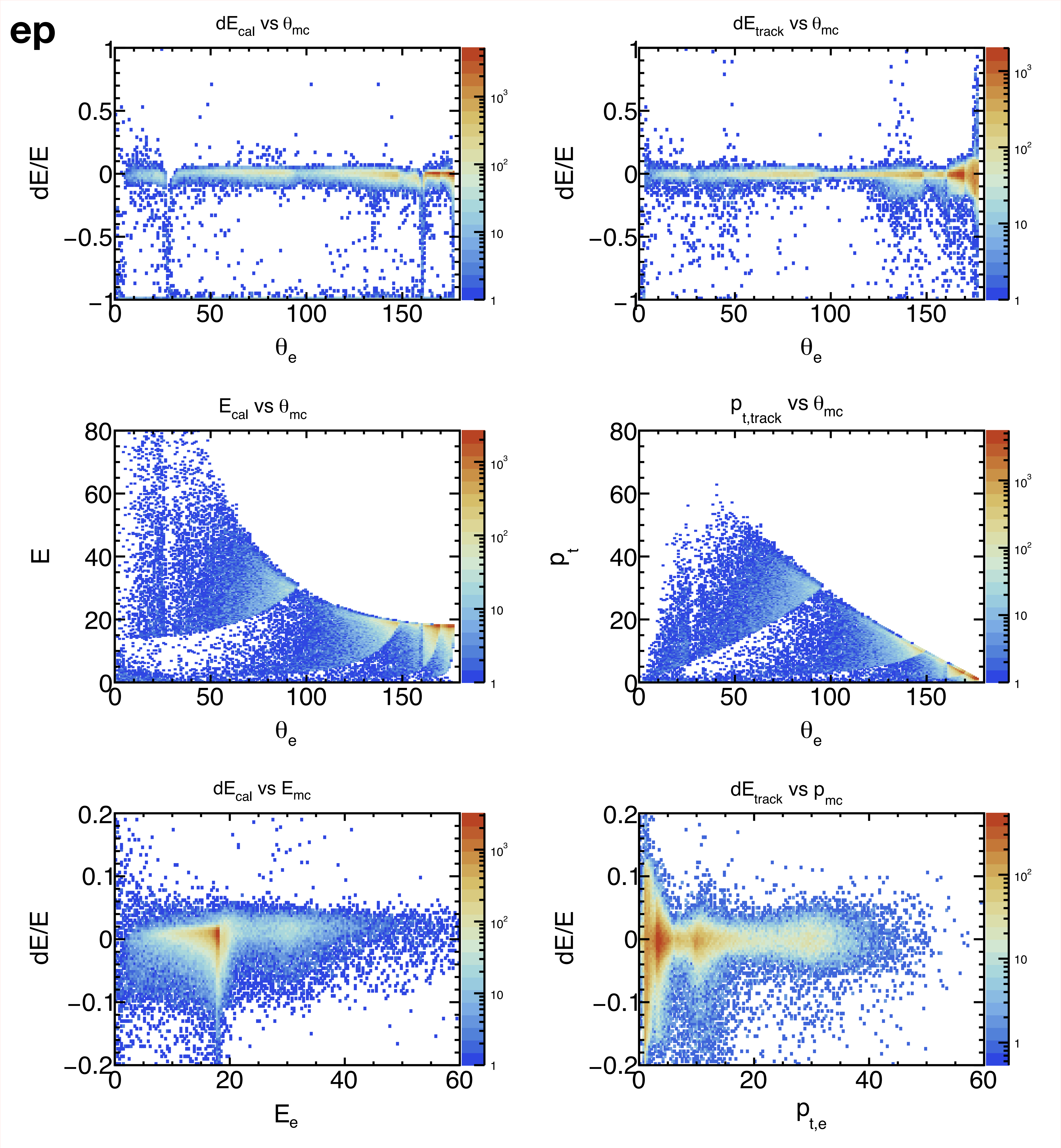
Thank you!

Slide++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Ee
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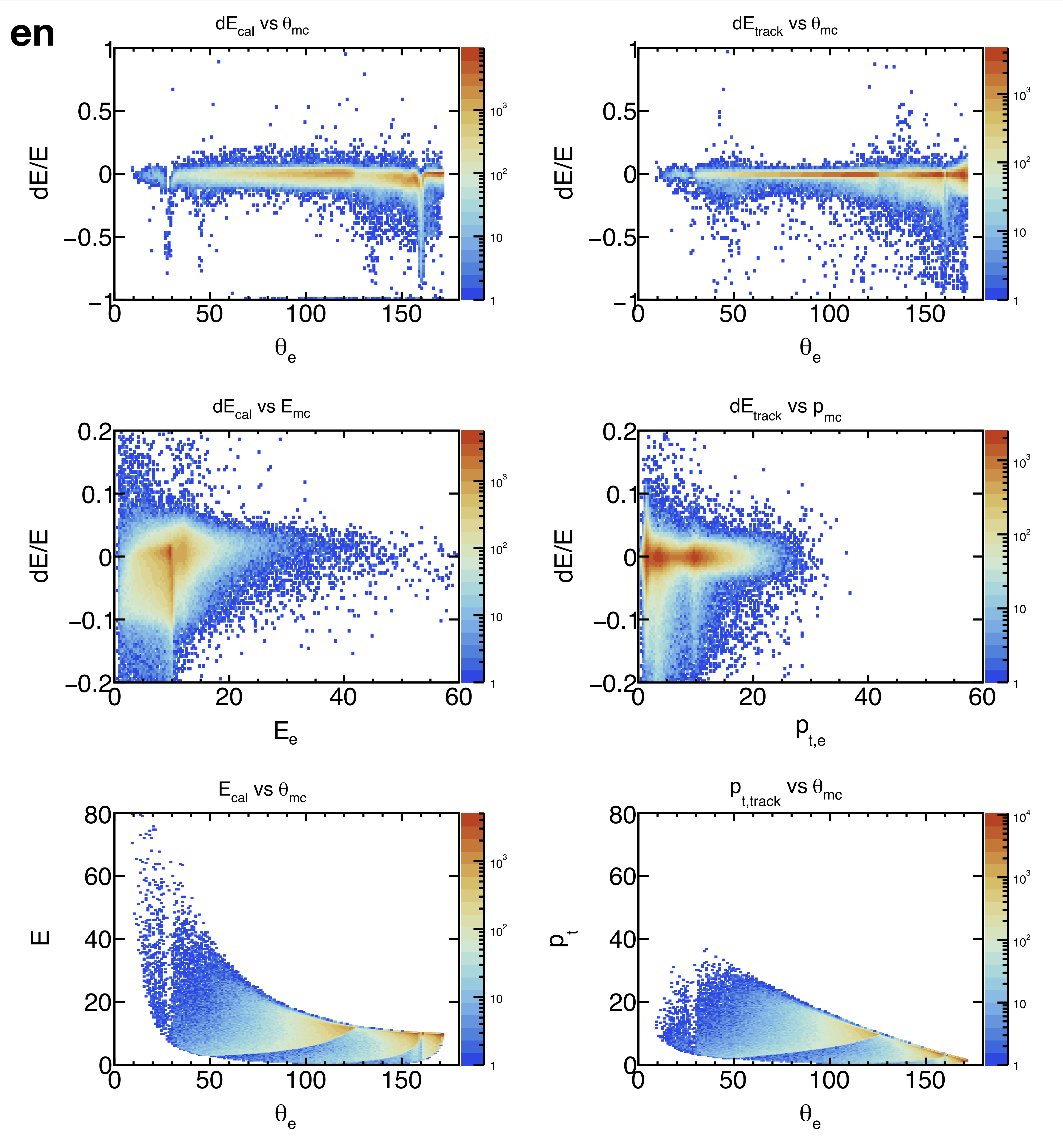
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dEcal vs Emc
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dE/E
E
pt
θe
Ee
pt,e