A_1^n and g_1^n from polarized eHe3 DIS with double spectator tagging

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EIC Early Science Workshop
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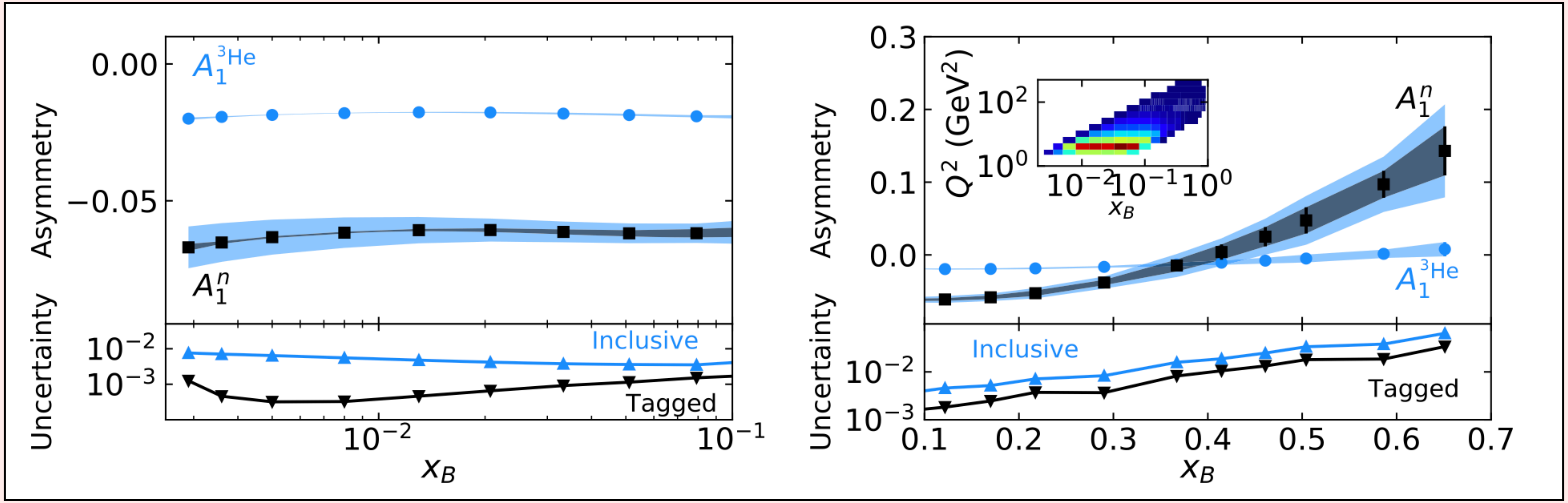
Stony Brook University

Center for Frontiers in Nuclear Science

ePIC

Double spectator tagging

Comparison of A_1^n extracted from inclusive (blue band) vs tagged (black square) measurements



5x41 GeV, $\mathscr{L} = 100\ \mathrm{fb}^{-1}$ (per nucleon)

Friščić et al. Neutron Spin Structure from e-³He Scattering with Double Spectator Tagging at the Electron-Ion Collider. *Phys. Lett. B* 2021

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Nuclear effect:

(For $10^{-4} \le x \le 0.8$)

- Spin depolarization
- Blinding
- Fermi motion
- Off-shell effect
- Non-nucleonic degrees of freedom
- Nuclear shadowing and anti-shadowing

$$A_1^n = \frac{F_2^{^3\mathrm{He}}[A_1^{^3\mathrm{He}} - 2(F_2^p/F_2^{^3\mathrm{He}})P_p A_1^p(1 - 0.014/(2P_p))]}{P_n F_2^n(1 + 0.056/P_n)}$$

TABLE X. Total uncertainties for A_1^n.

$\langle x \rangle$	0.33	0.47	0.60
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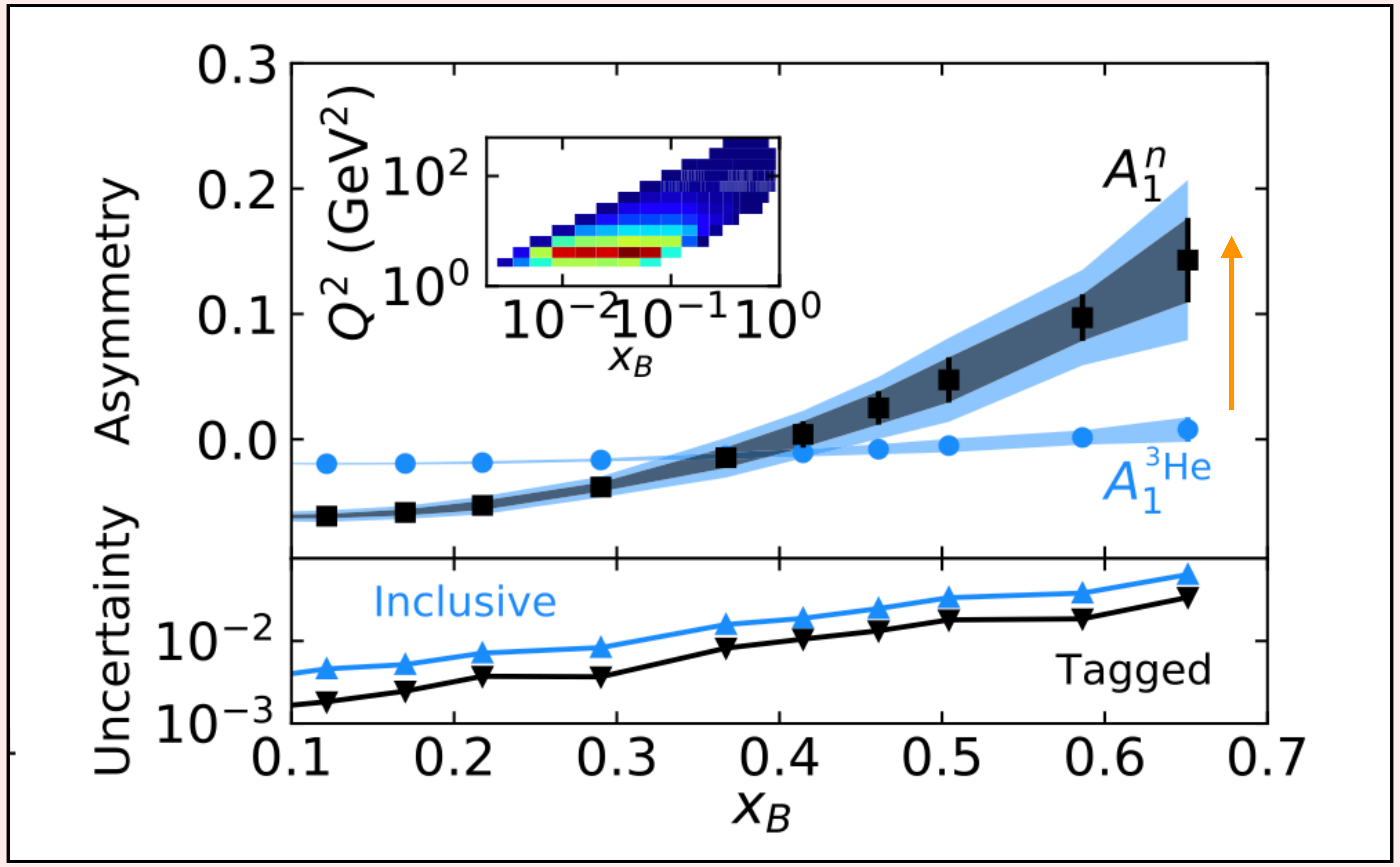
correction due to $\Delta(1232)$ in $^3\mathrm{He}$ wave function



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Data comparison

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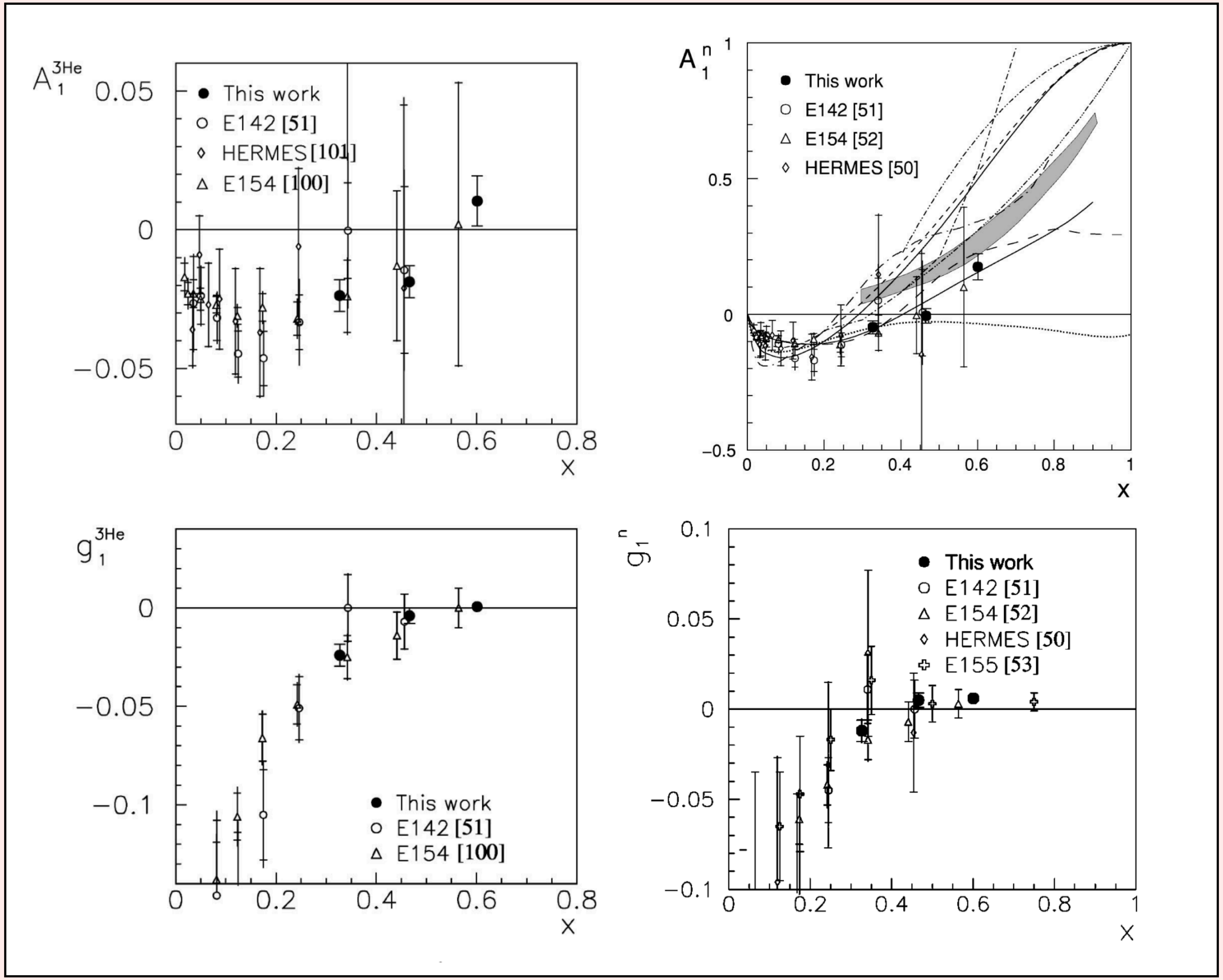

- A_1^n exacted using this model agrees with HERA data

Double spectator tagging

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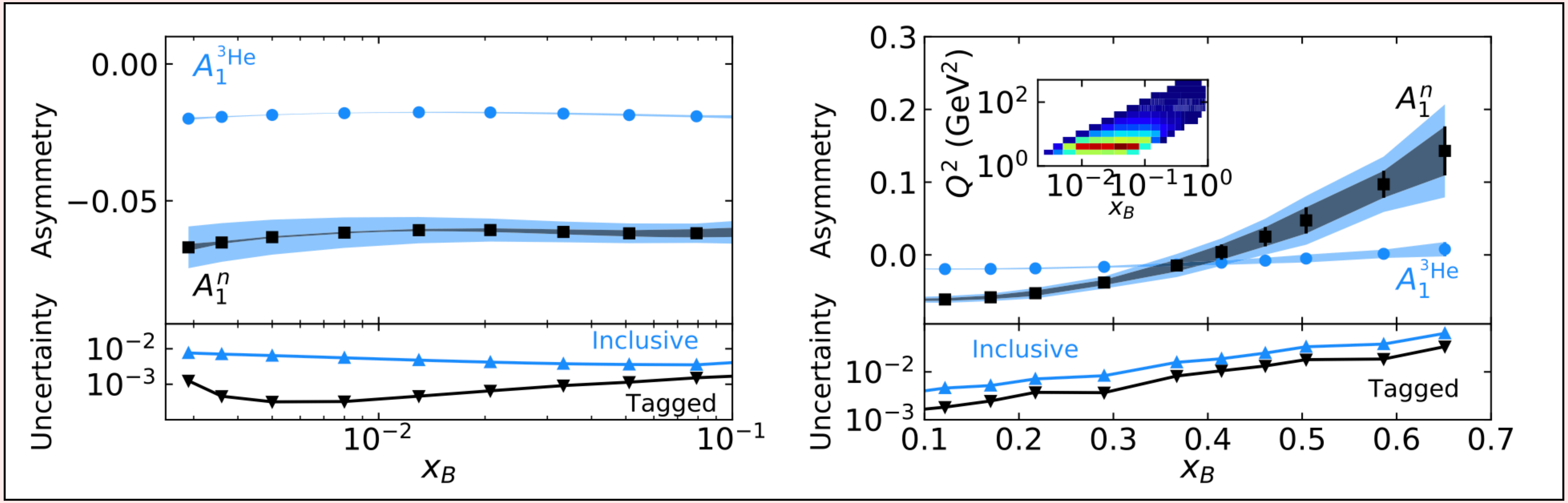

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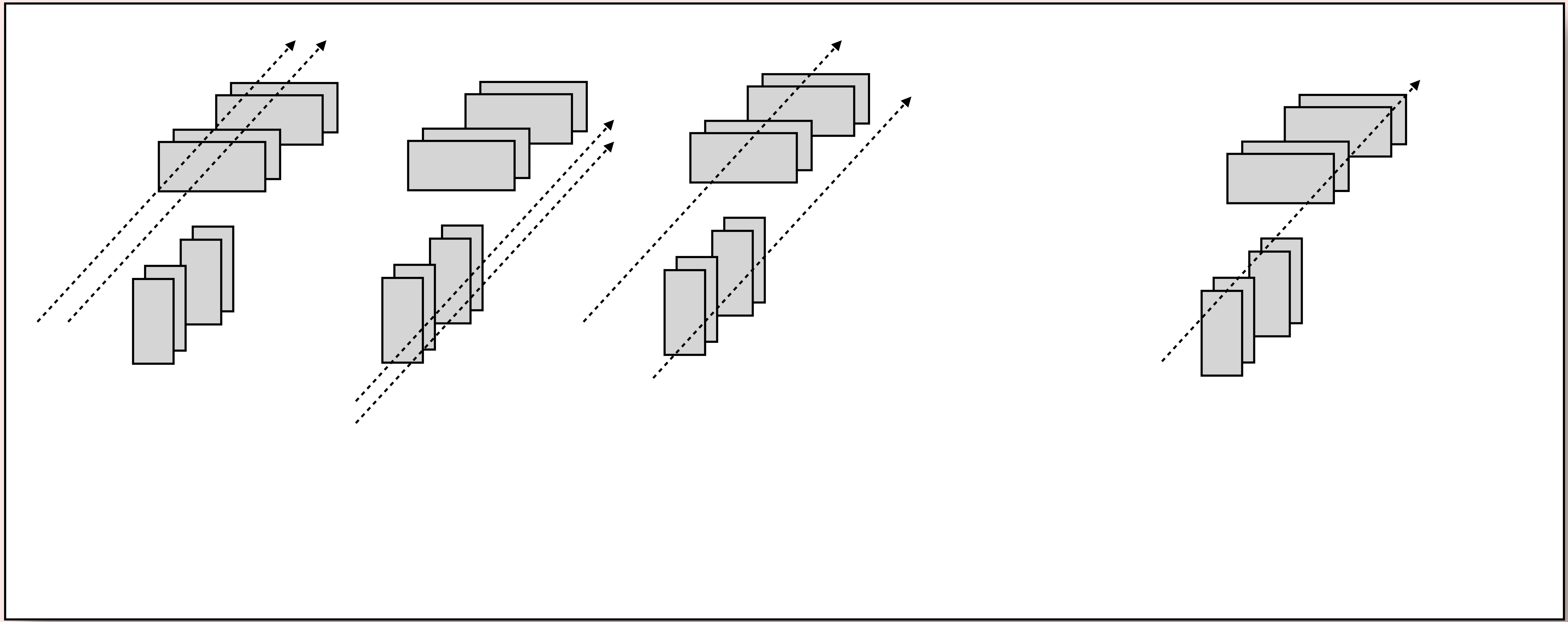
Spectator tagging

- Track reconstruction is not ready for e^{3}He events, so currently:
- Define proton track: at least one hit per plane per detector (either RP or OMD)
- If there are two proton tracks, then the event is tagged as en scattering.



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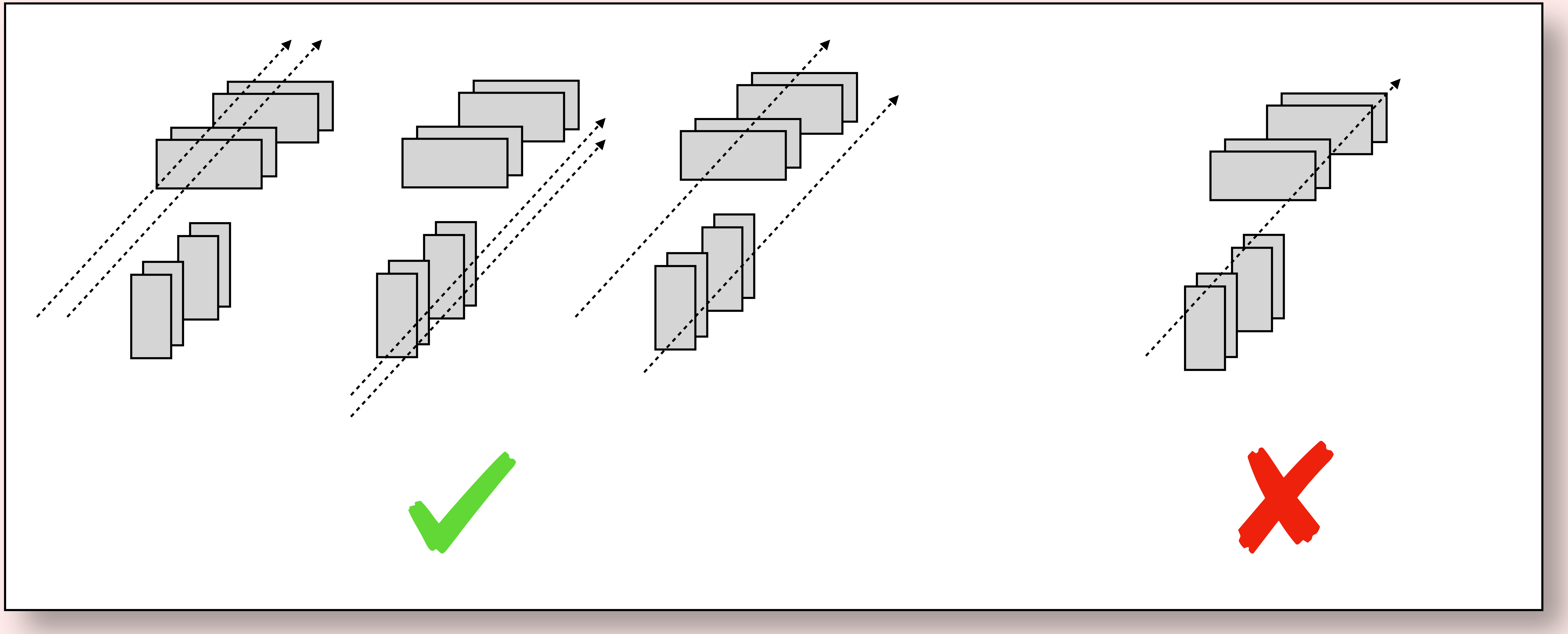
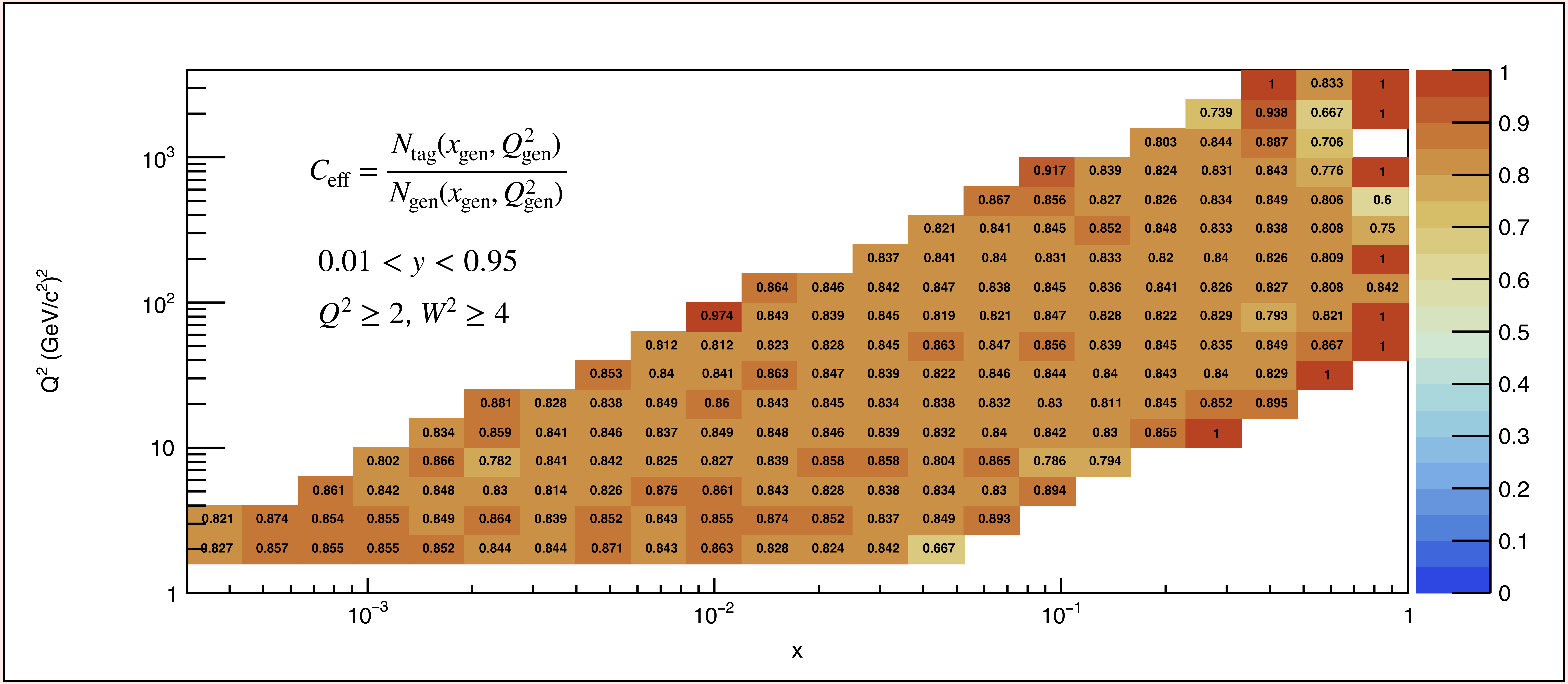


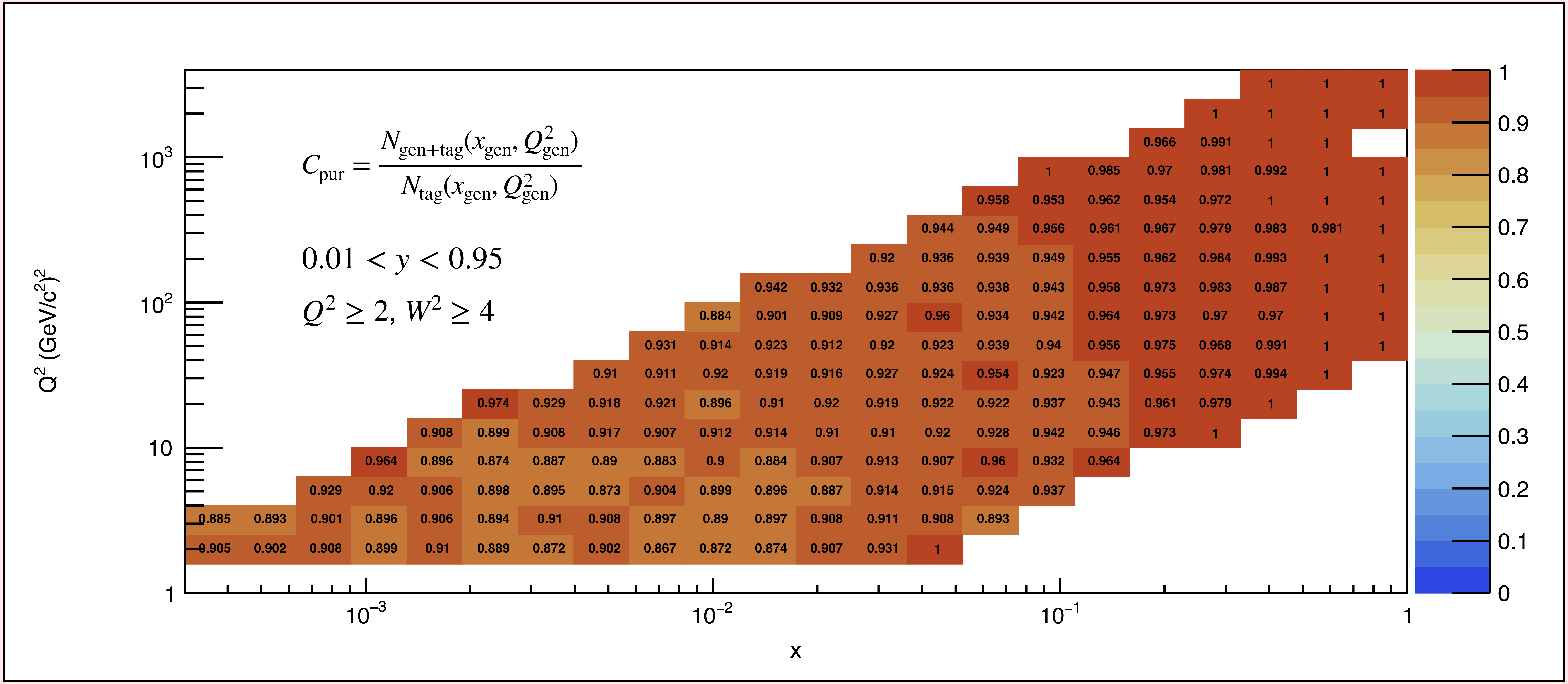
Tagging efficiency

- Overall uniform with bin efficiency $\gtrsim 80\,\%$

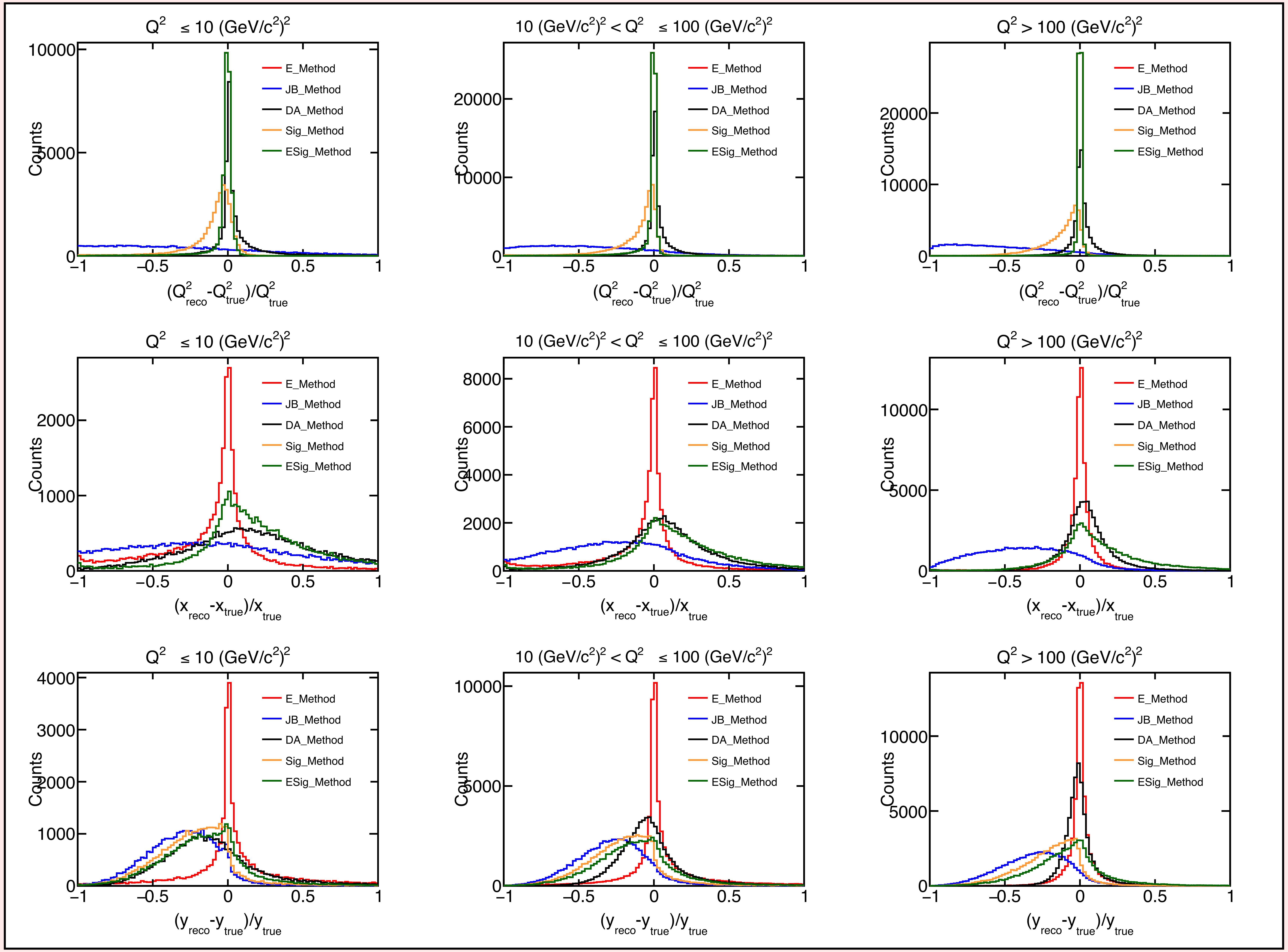


Tagging purity

- Overall uniform with bin purity $\gtrsim 90\,\%$



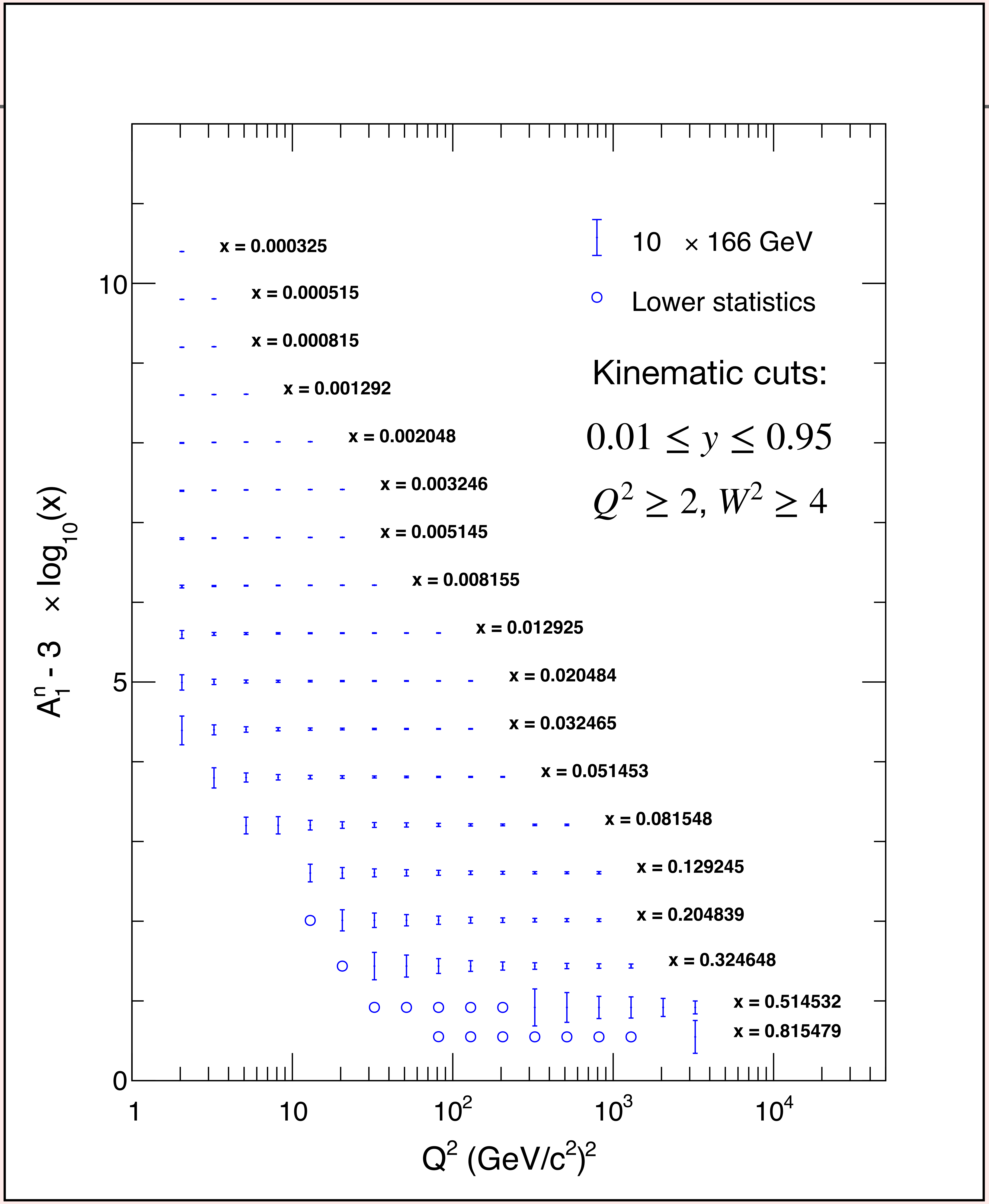
Electron kinematic reconstruction



- Use MC info to find reconstructed electrons
- BeAGLE does not include radiative effect
- Currently using “electron method” only

A_1^n for early science

- $A_1(x, Q^2) \equiv \dfrac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \dfrac{A_\parallel}{D(1+\eta\xi)} - \dfrac{\eta A_\perp}{d(1+\eta\xi)}$
- $\mathscr{L} = 8.65\ \text{fb}^{-1}, P_e = P_n = 70\,\%$
- Data split evenly between $A_\parallel$ and $A_\perp$
- $\delta A_{\parallel,\perp} = \dfrac{1}{\sqrt{N} P_e P_N}$
- Bin A_1 calculated from: Doi: 10.2172/824895
- Statistical uncertainty only, correction not yet applied



g_1^n for early 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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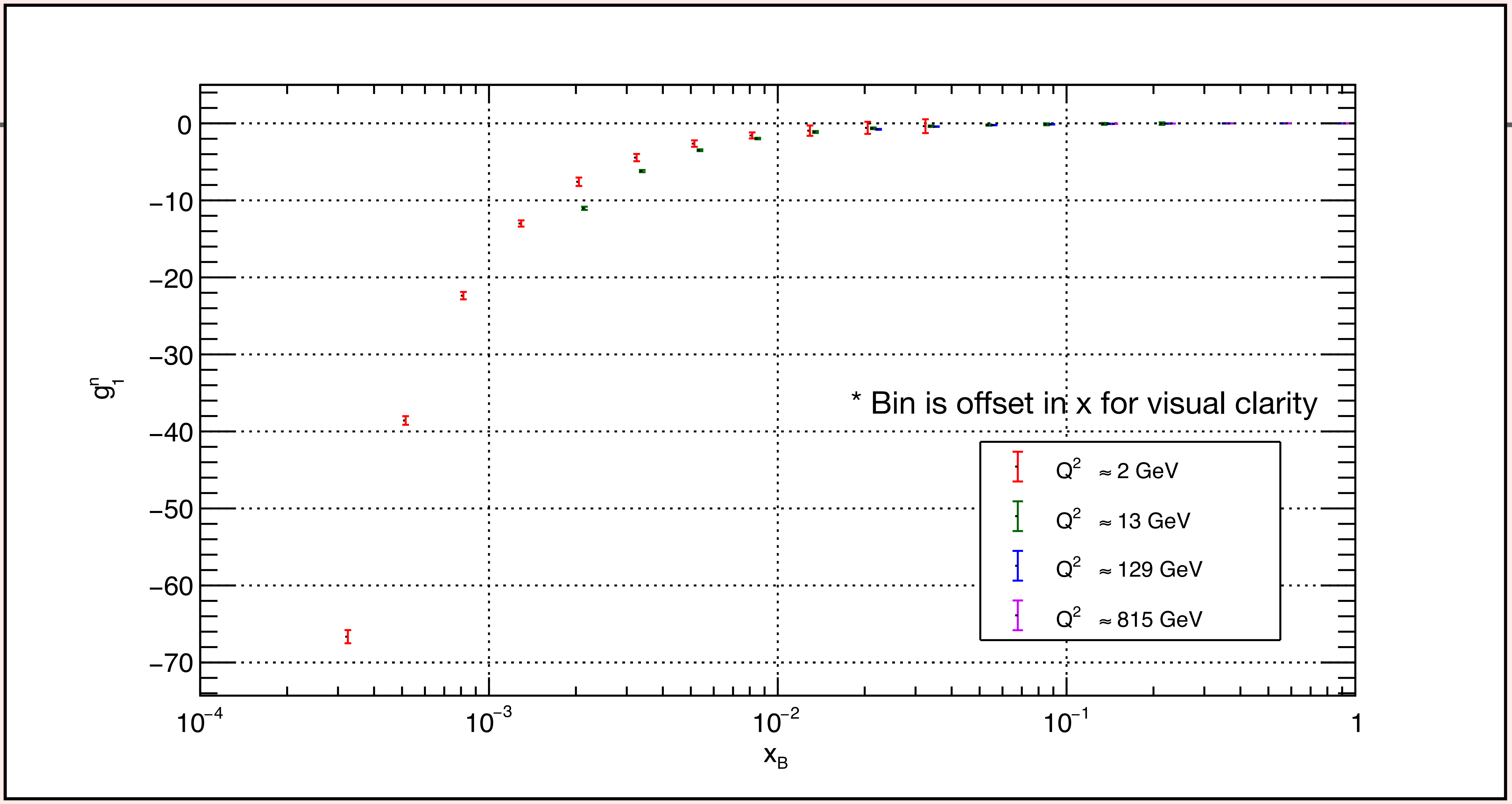
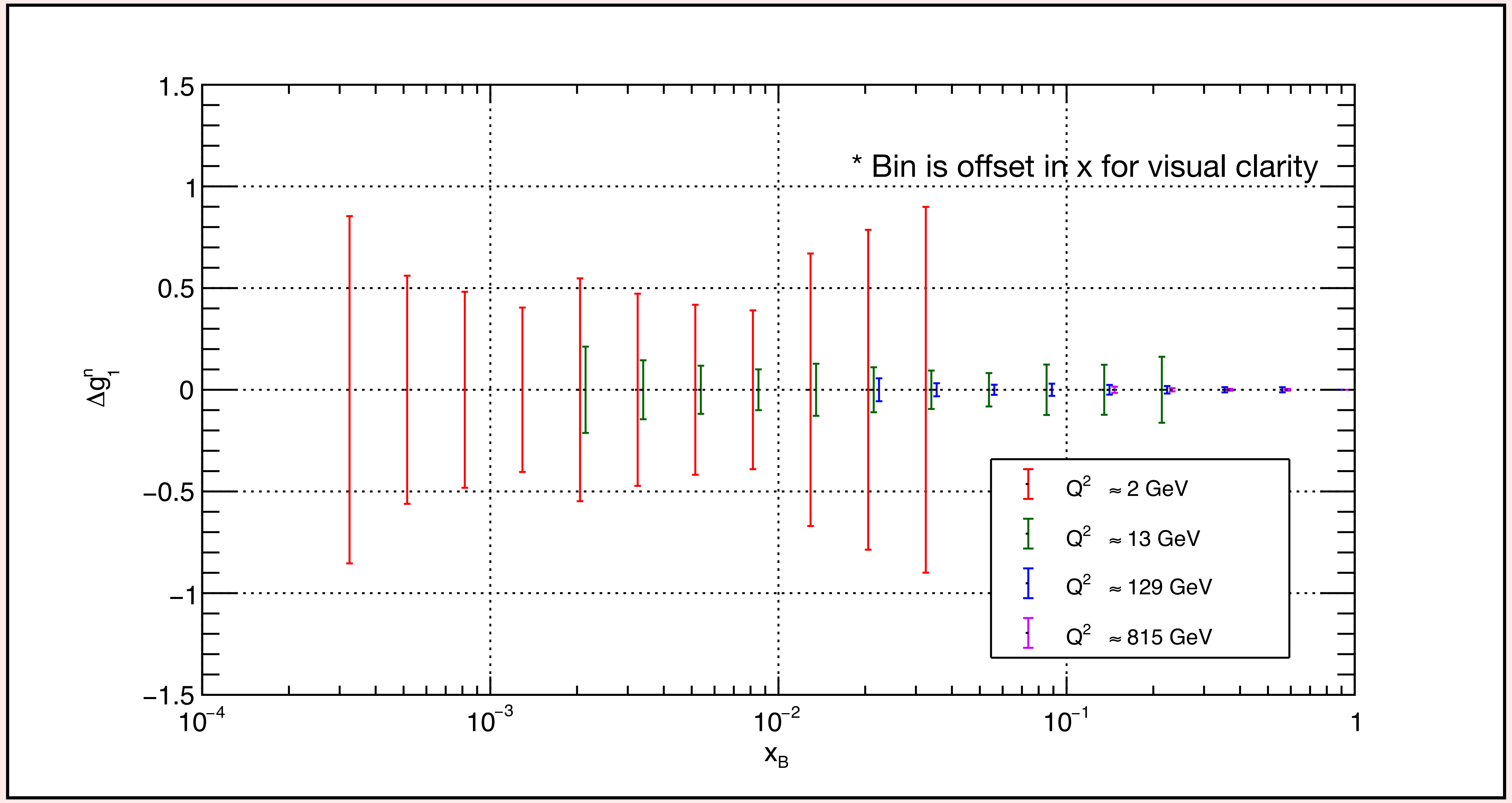
- $\delta A_{\parallel,\perp} = \frac{1}{\sqrt{N} P_e P_N}$
- Bin A_1 calculated from: Doi: 10.2172/824895
- Statistical uncertainty only, correction not yet applied
- $A_1 \approx g_1/F_1$
- F_1 taken from HERAPDF20_LO_EIG





Extract α_s via A_1^p and A_1^n

EIC Early Science Timeline

	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

$$\boxed{\begin{matrix} A_1^n \\ g_1^n \end{matrix}} + \boxed{\begin{matrix} A_1^p \\ g_1^p \end{matrix}} \rightarrow \boxed{\alpha_s}$$

- Bjorken integral:

$$\Gamma_1^{\mathrm{p-n}} \equiv \int_0^{1^-} (g_1^p - g_1^n)\, dx$$

- At finite Q² values:

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

Extract α_s via A_1^p and A_1^n

EIC can be a significant contributor to the global extraction of α_s:

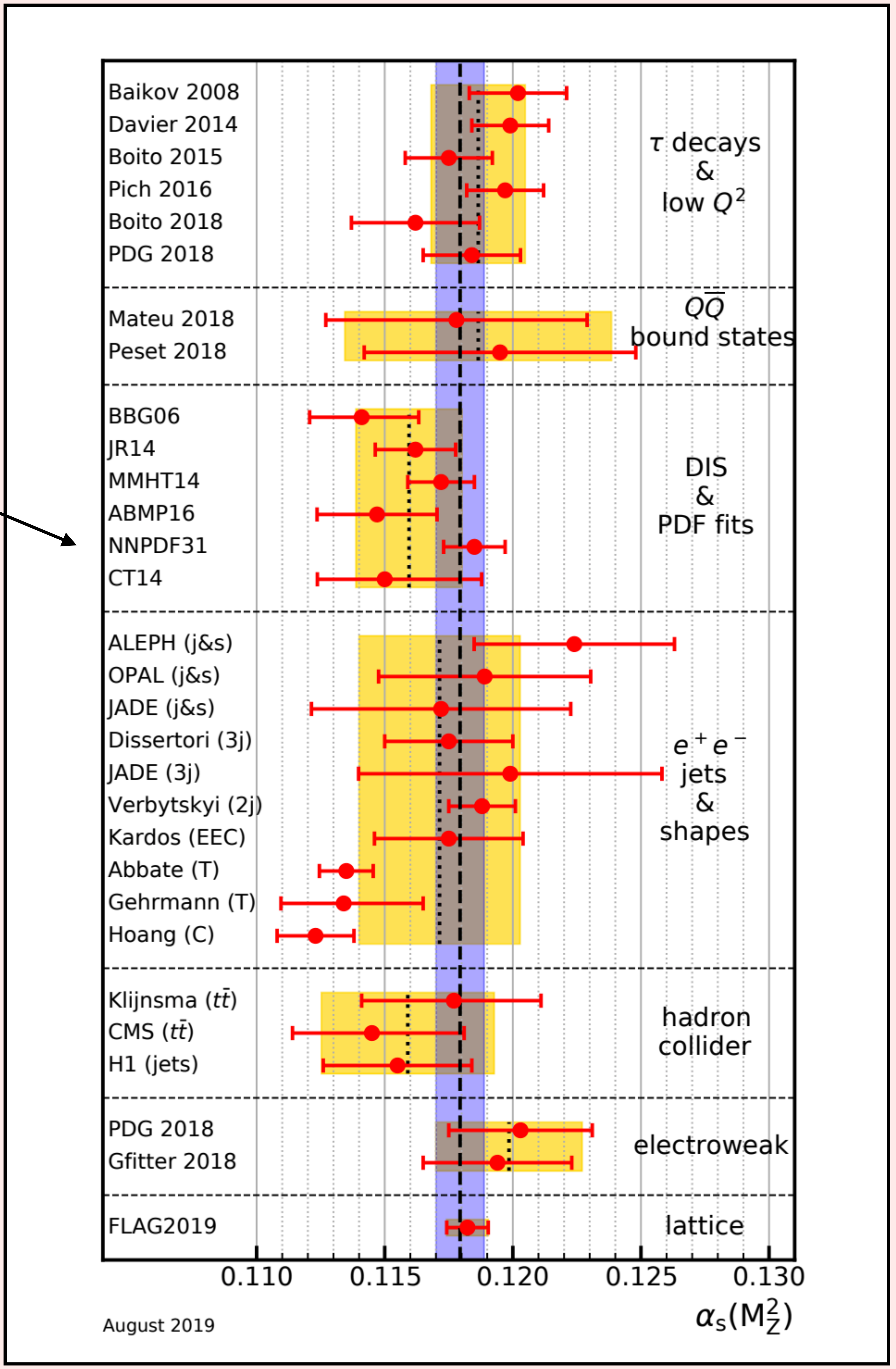
- Global PDF fits

  Cerci *et al.* Extraction of the strong coupling with HERA and EIC inclusive data. *Eur. Phys. J. C 2023*

- Using BJSR

  Kutz *et al.* High precision measurements of α_s at the future EIC. *Phys. Rev. D 2024*

$$\boxed{\begin{matrix} A_1^n \\ g_1^n \end{matrix}} + \boxed{\begin{matrix} A_1^p \\ g_1^p \end{matrix}} \rightarrow \boxed{\alpha_s}$$



P. A. Zyla *et al.* (Particle Data Group), Review of Particle Physics. *PTEP 2020*

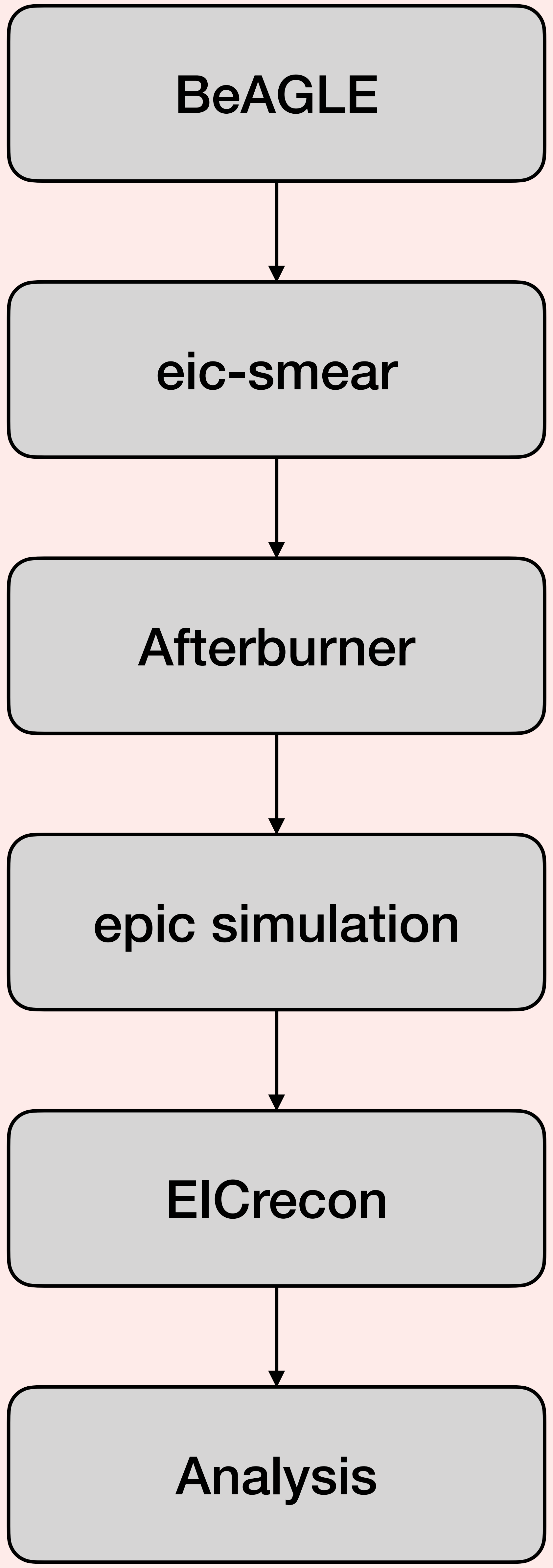
Slides+ : analysis QA

Analysis status & QA checklist

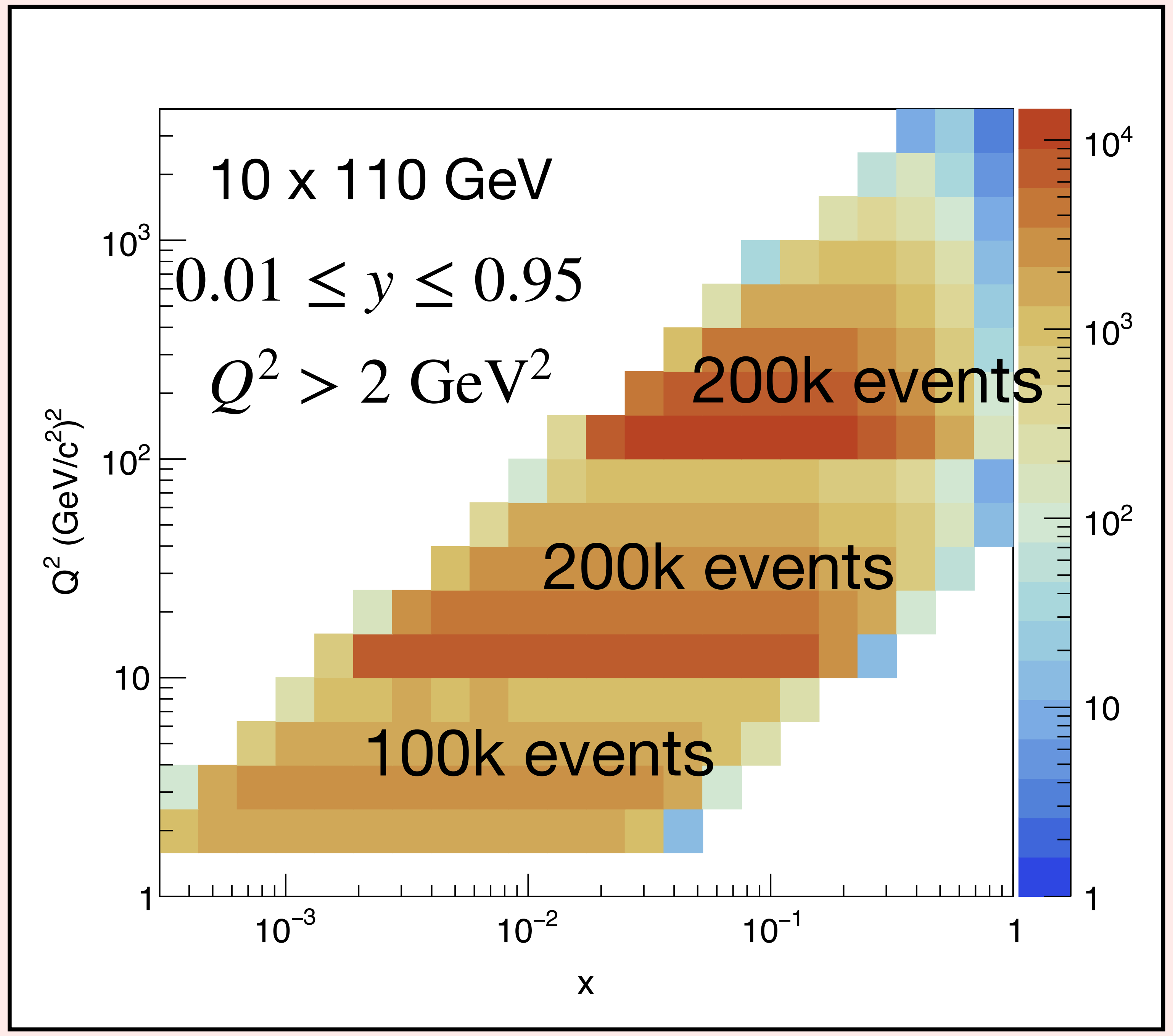
https://docs.google.com/presentation/d/1nSJGFxWLkfE6dPkl-VMcOyVpJWkmOTN0UgKXCCFTUqQ/edit?slide=id.g34d71ddcf31_0

Kinematic reconstructions	quantity	Reco	Truth	Response (2D)	Purity/bin migration	detector acceptance-only corrected	Unfolding/full correction
(electron,JB, DA,sigma, e-sigma)	Q2	☑	☑	☑	☑	☐	☐
	x	☑	☑	☑	☑	☐	☐
	y	☑	☑	☑	☐	☐	☐
	dQ2/Q2	☑	☑	☑	☐	☐	☐
	dx/x	☑	☑	☑	☐	☐	☐
	dy/y	☑	☑	☑	☐	☐	☐
	e' energy	☐	☐	☐	☐	☐	☐
	e' theta	☐	☐	☐	☐	☐	☐
	HFS (E-pz)	☐	☐	☐	☐	☐	☐
	HFS (pT)	☐	☐	☐	☐	☐	☐
Event level		☐	☐	☐	☐	☐	☐
	E-pz (e'+HFS)	☐	☐	☐	☐	☐	☐
	E/p for calorimeter	☐	☐	☐	☐	☐	☐
	Calo clusters	☐	☐	☐	☐	☐	☐
Observable of interest		☐	☐	☐	☐	☐	☐
	e.g., t,u,etc.	☐	☐	☐	☐	☐	☐
Detector specific variables	Depends	☑	☑	☑	☑	☐	☐
PID quantities:	Add when it comes	☐	☐	☐	☐	☐	☐

Analysis procedure



e^{3}He events (not polarized):

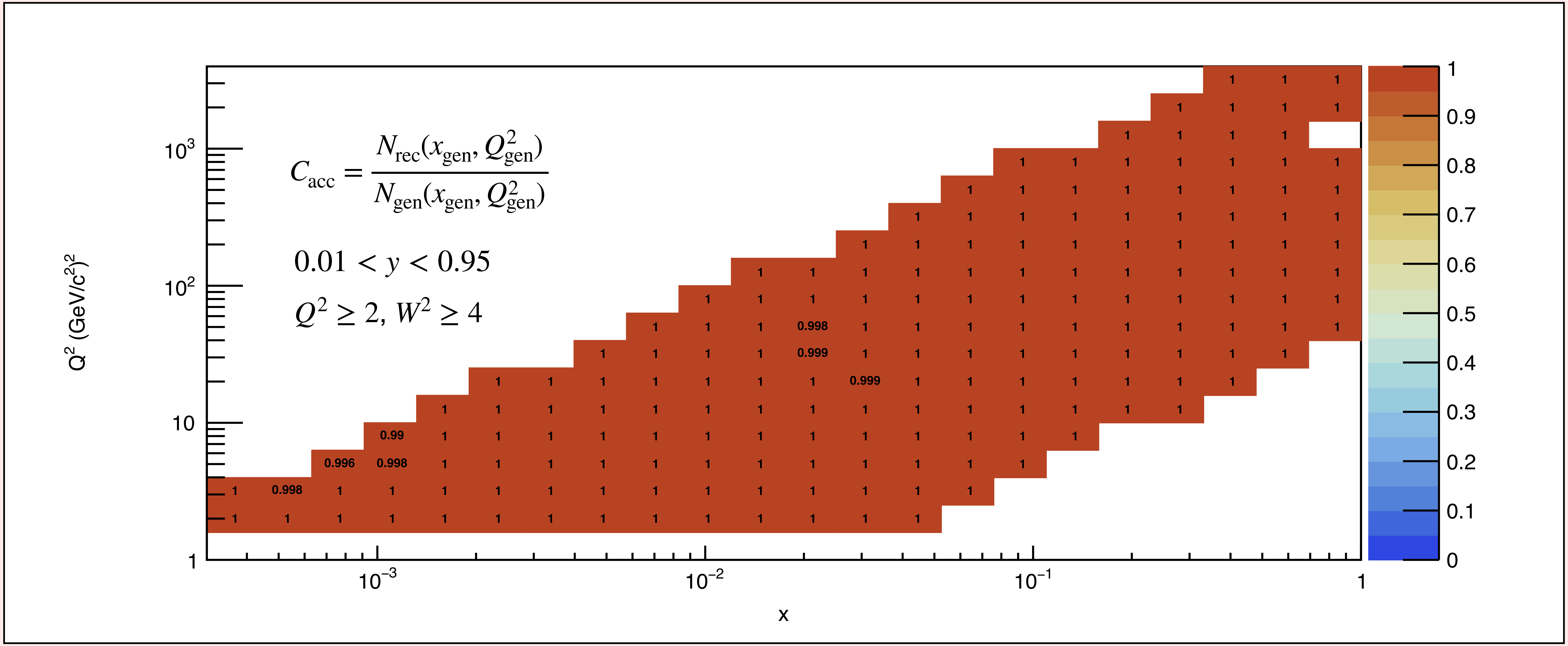


- EPIC 25.03.1 simulation campaign
- Later scaled to $\mathscr{L} = 8.65$ fb^{-1}

- Electron identification and kinematic reconstruction was done outside of EICRecon

eID acceptance

- Use truth information to identify scattered electron from reconstruction
- Use reconstruction information to calculate x and Q^2



eID bin migration

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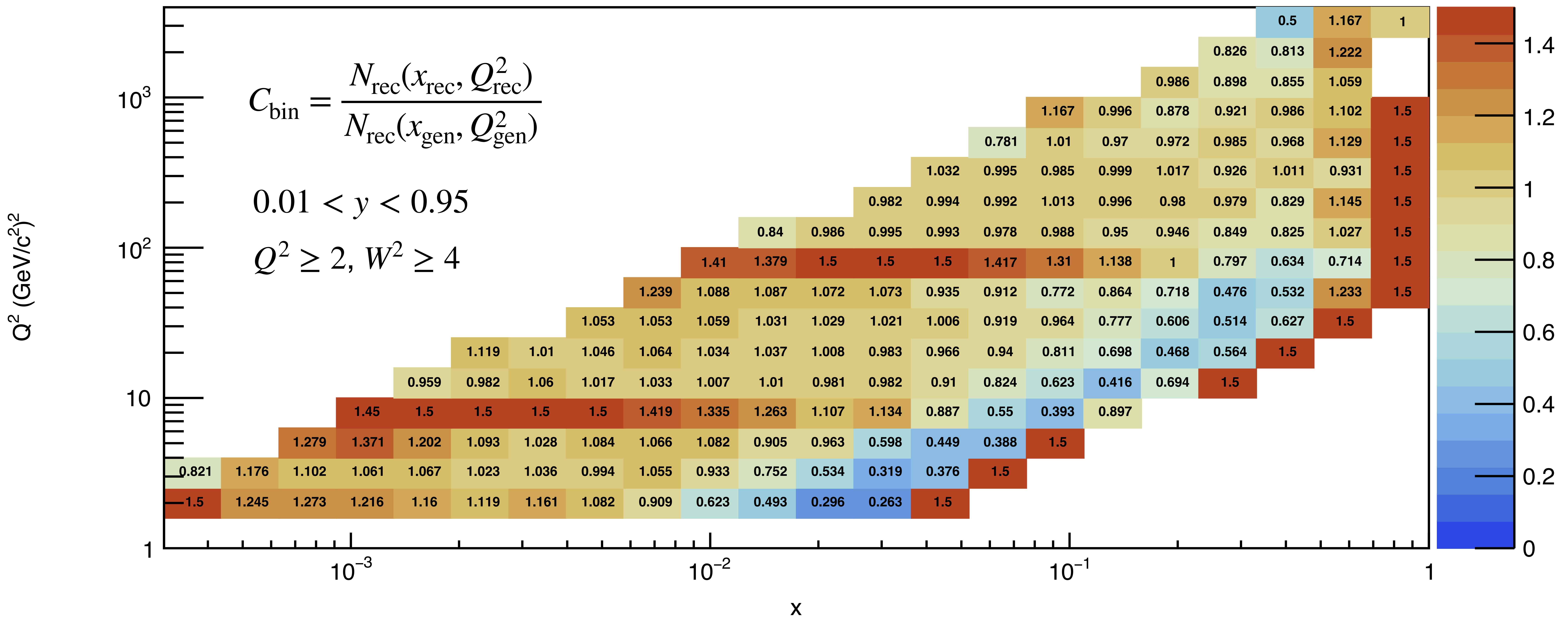

Electron kinematic reconstruction

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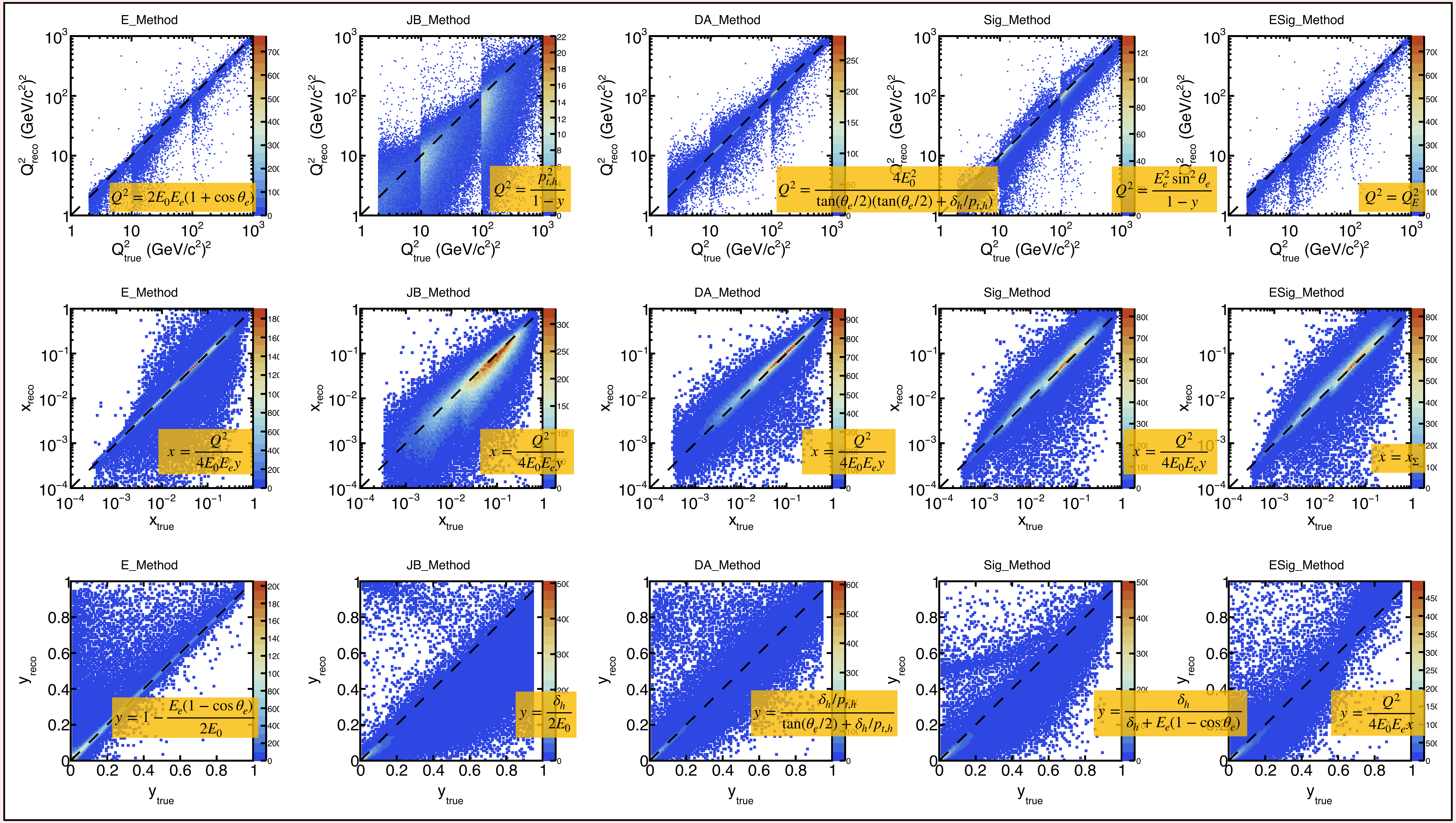

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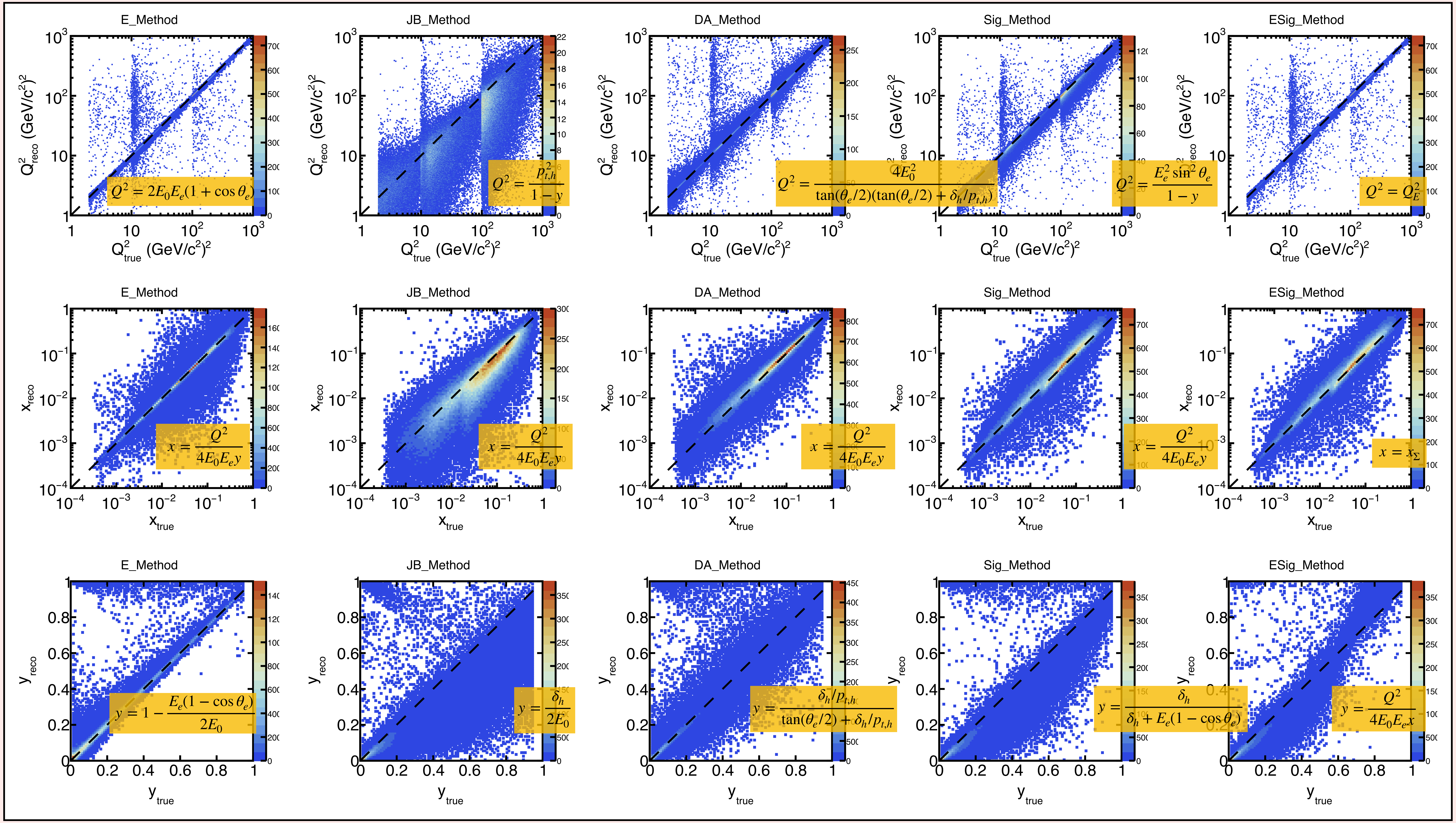

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(For $10^{-4} \leq x \leq 0.8$)

$$g_1^{^3\mathrm{He}} = P_n g_1^n + 2P_p g_1^p - 0.014[g_1^p(x) - 4g_1^n(x)] + a(x)g_1^n(x) + b(x)g_1^p(x)$$

effective polarization of n(p) in $^3\mathrm{He}$

nuclear shadowing and anti-shadowing effects

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