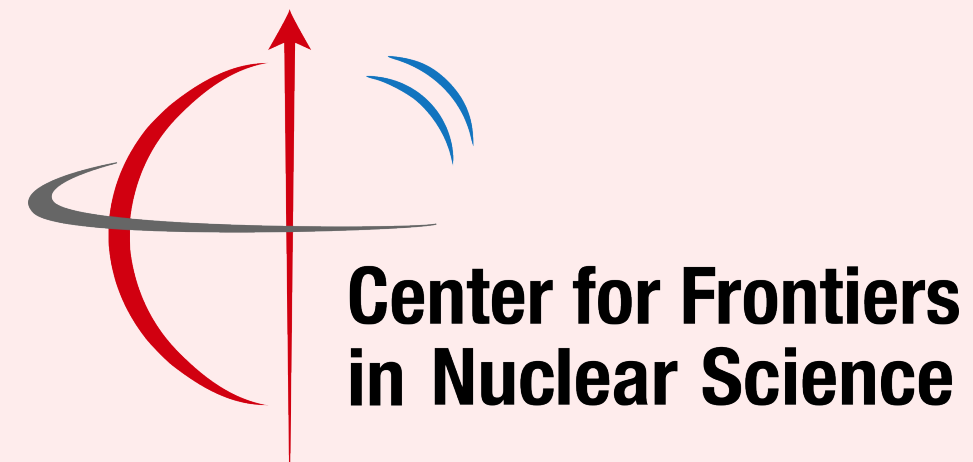
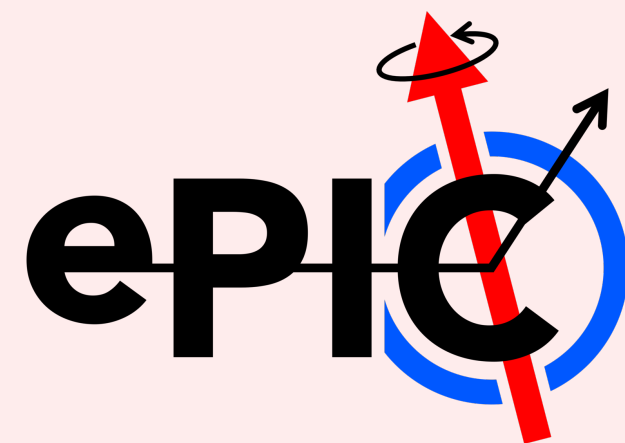


α_s extraction from the Bjorken sum rule at ePIC early running

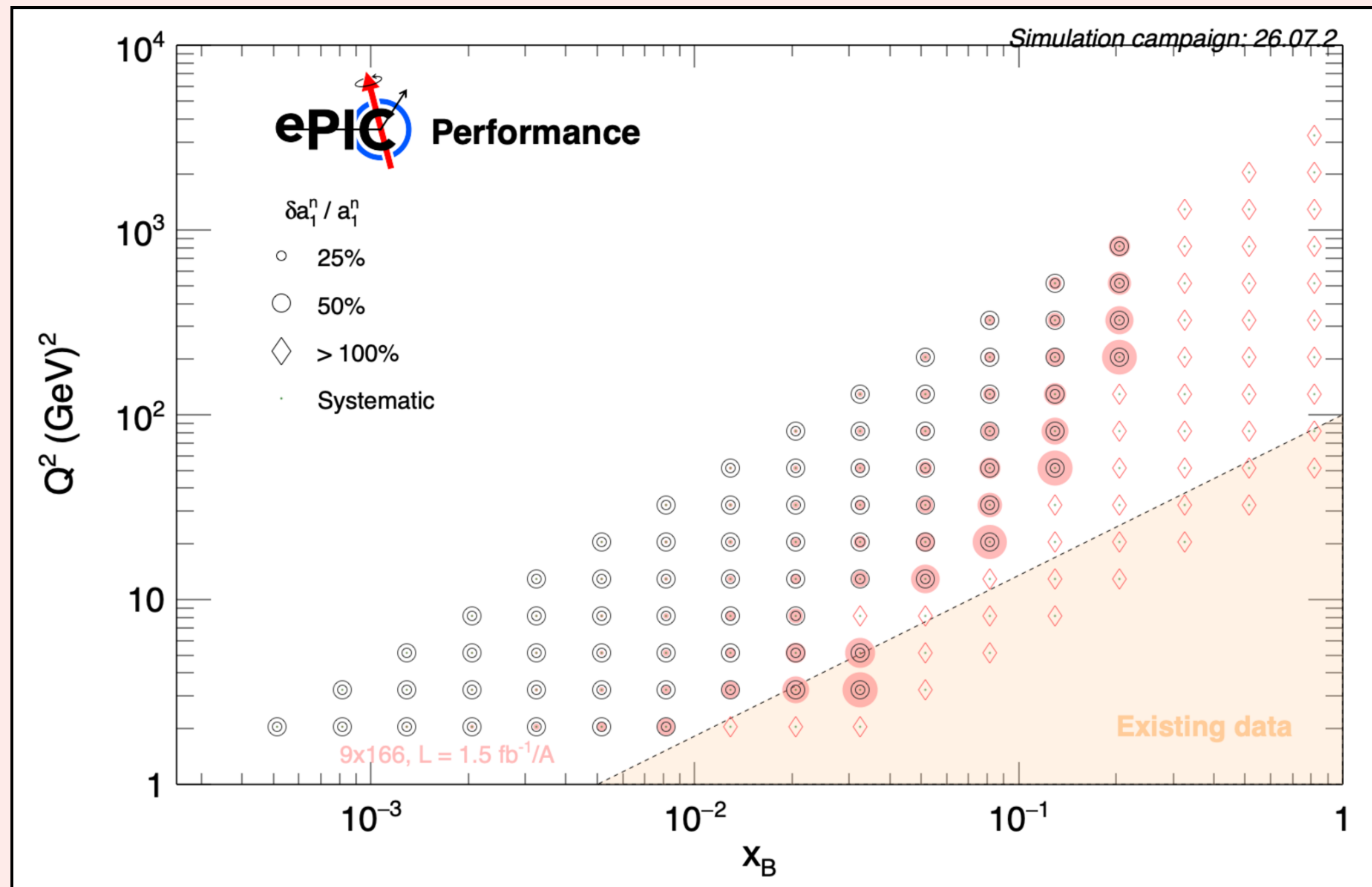
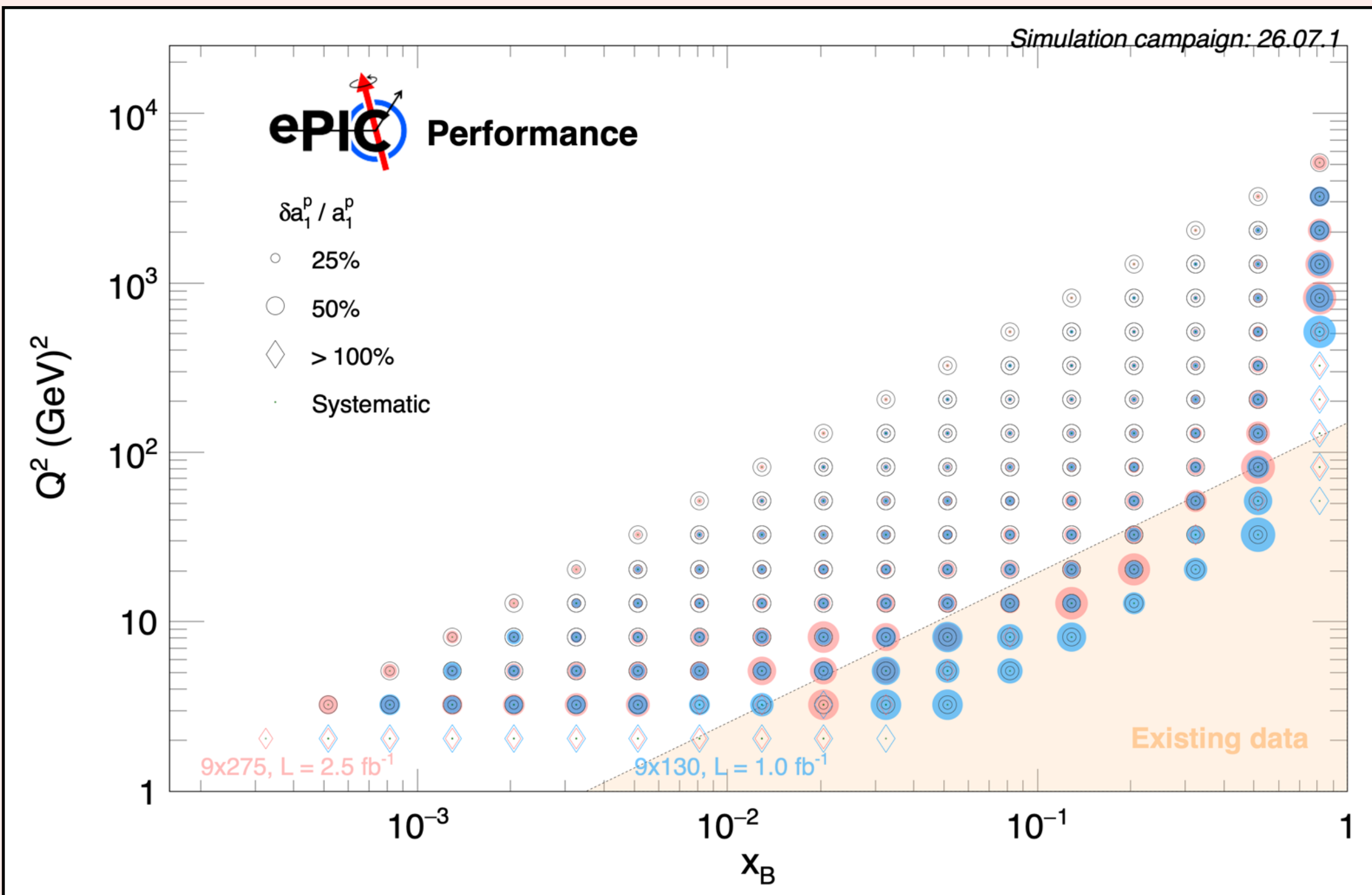
Win Lin
Stony Brook University

CFNS Friday Meeting
10/02/2026



Polarized DIS during EIC early running

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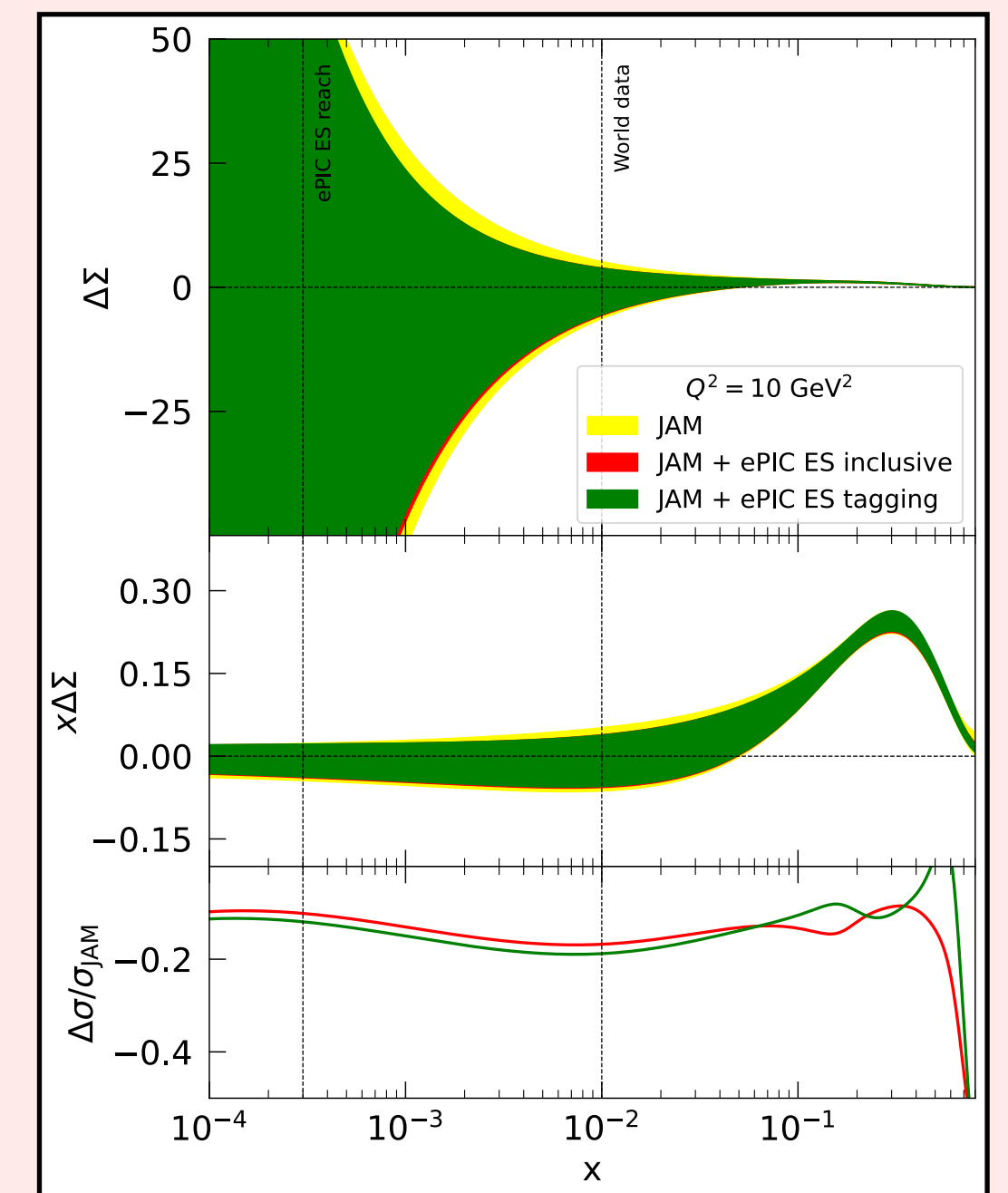
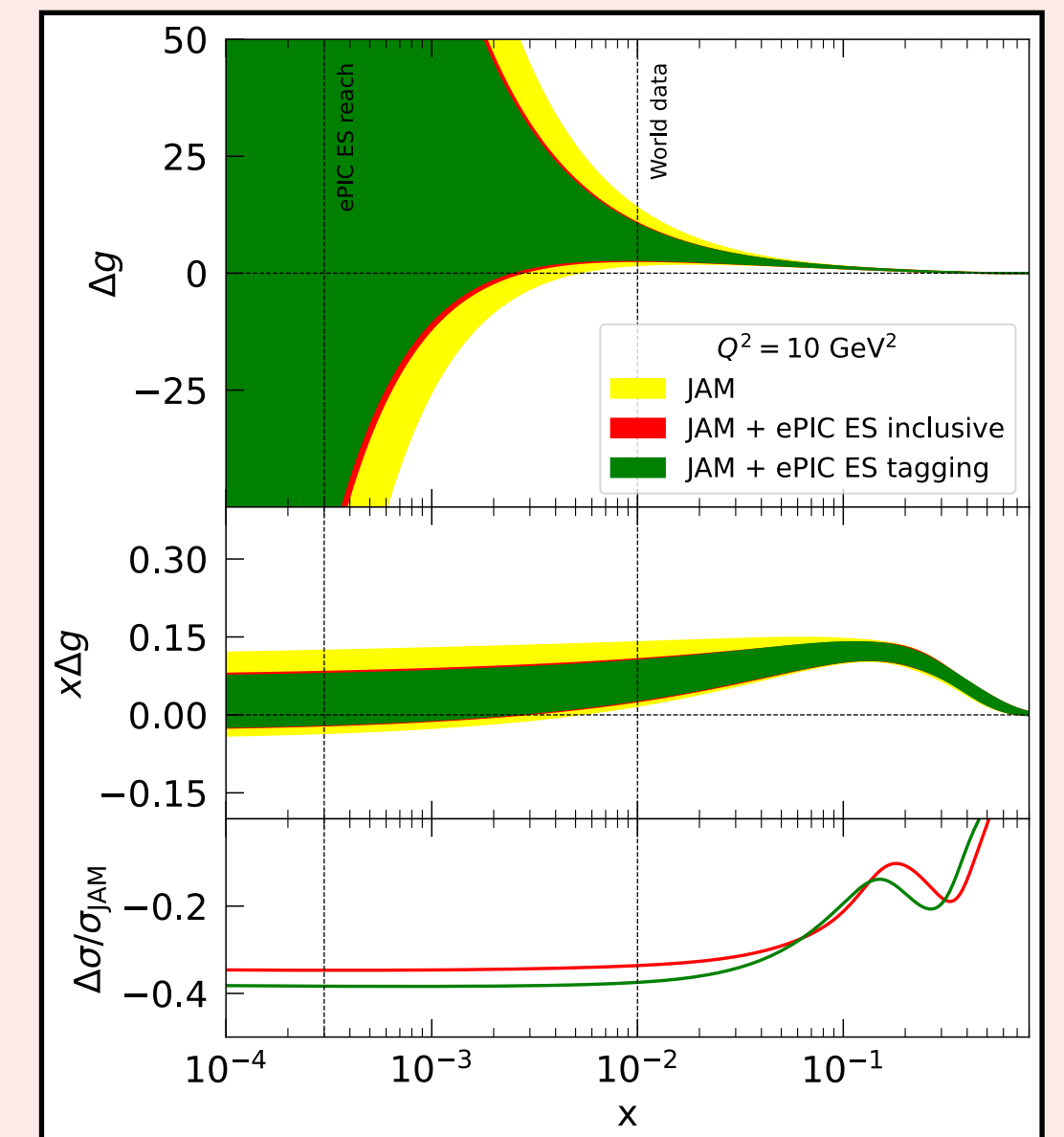
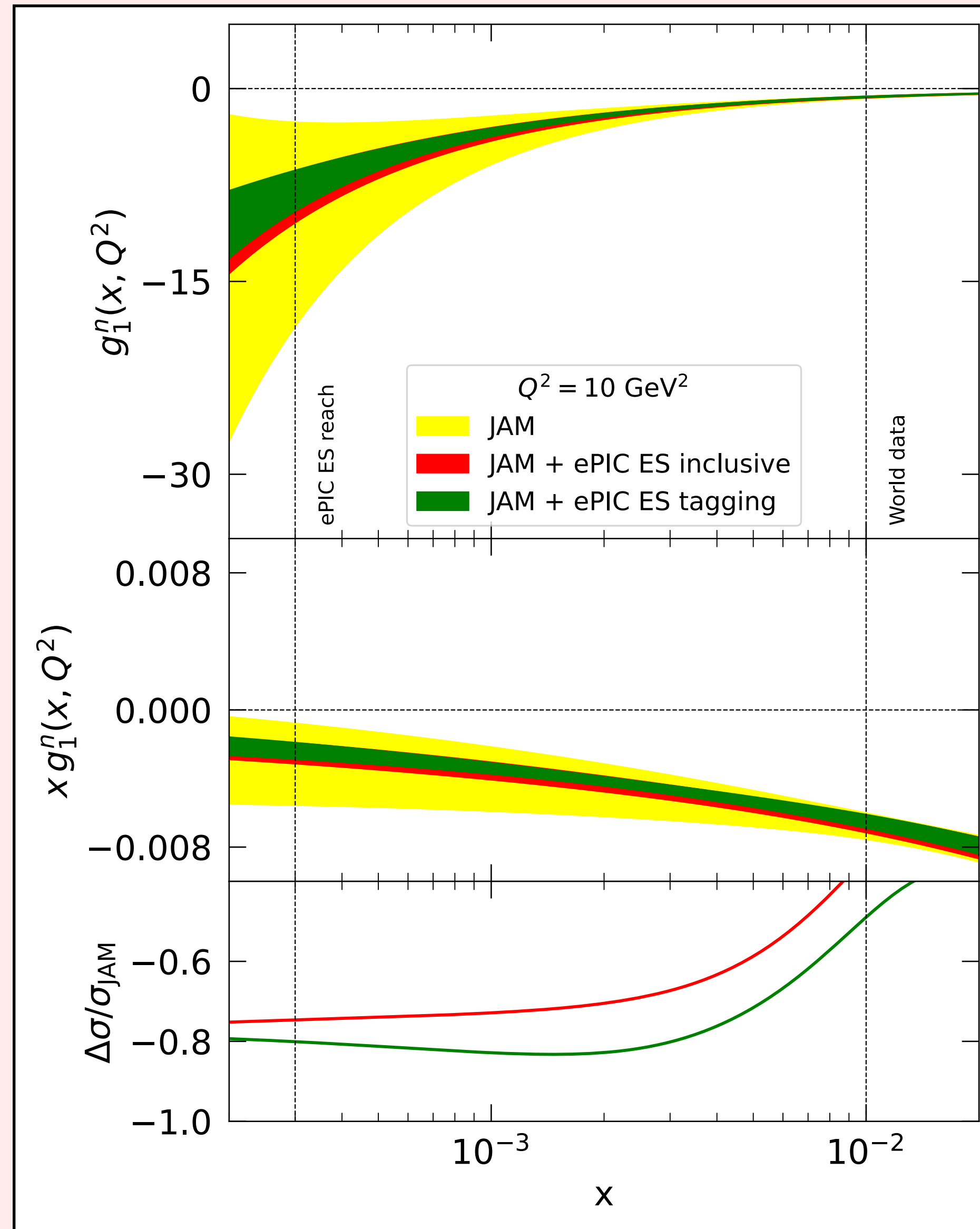
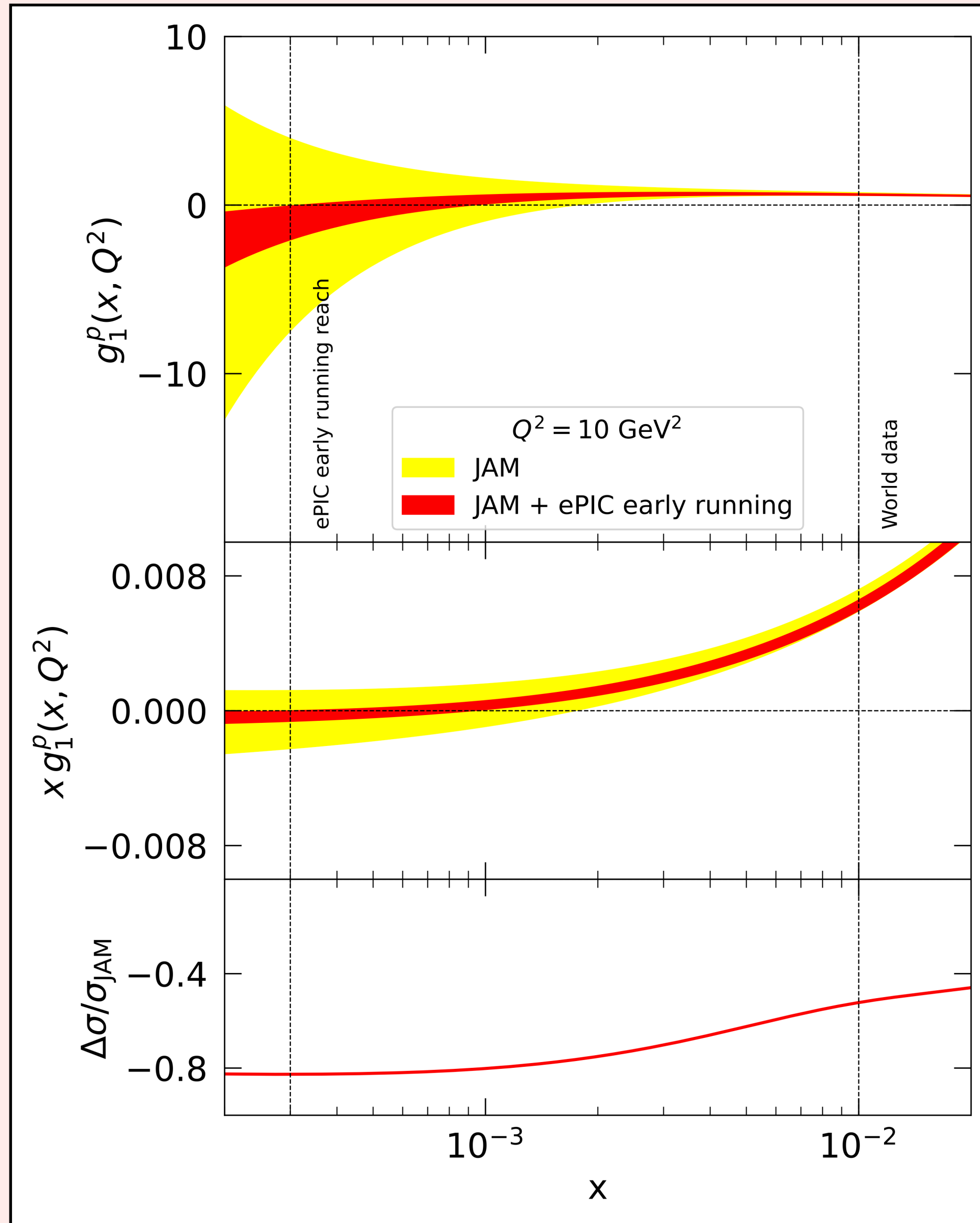


$$A_1(x, Q^2) \equiv \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \frac{A_{\parallel}}{D(1 + \eta\xi)} - \frac{\eta A_{\perp}}{d(1 + \eta\xi)}$$

$$A_2(x, Q^2) \equiv \frac{2\sigma_{LT}}{\sigma_{1/2} + \sigma_{3/2}} = \frac{\xi A_{\parallel}}{D(1 + \eta\xi)} + \frac{A_{\perp}}{d(1 + \eta\xi)}$$

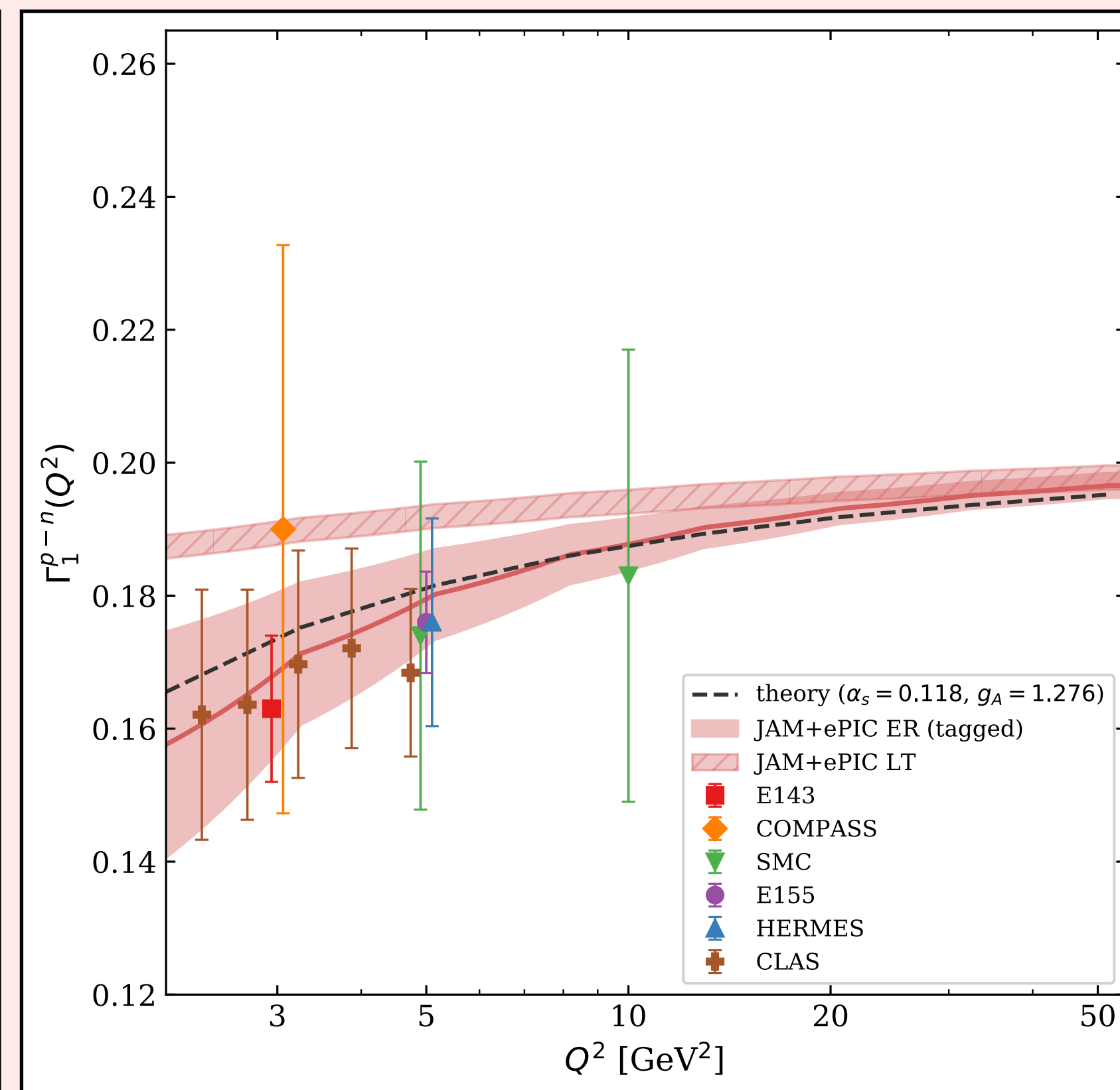
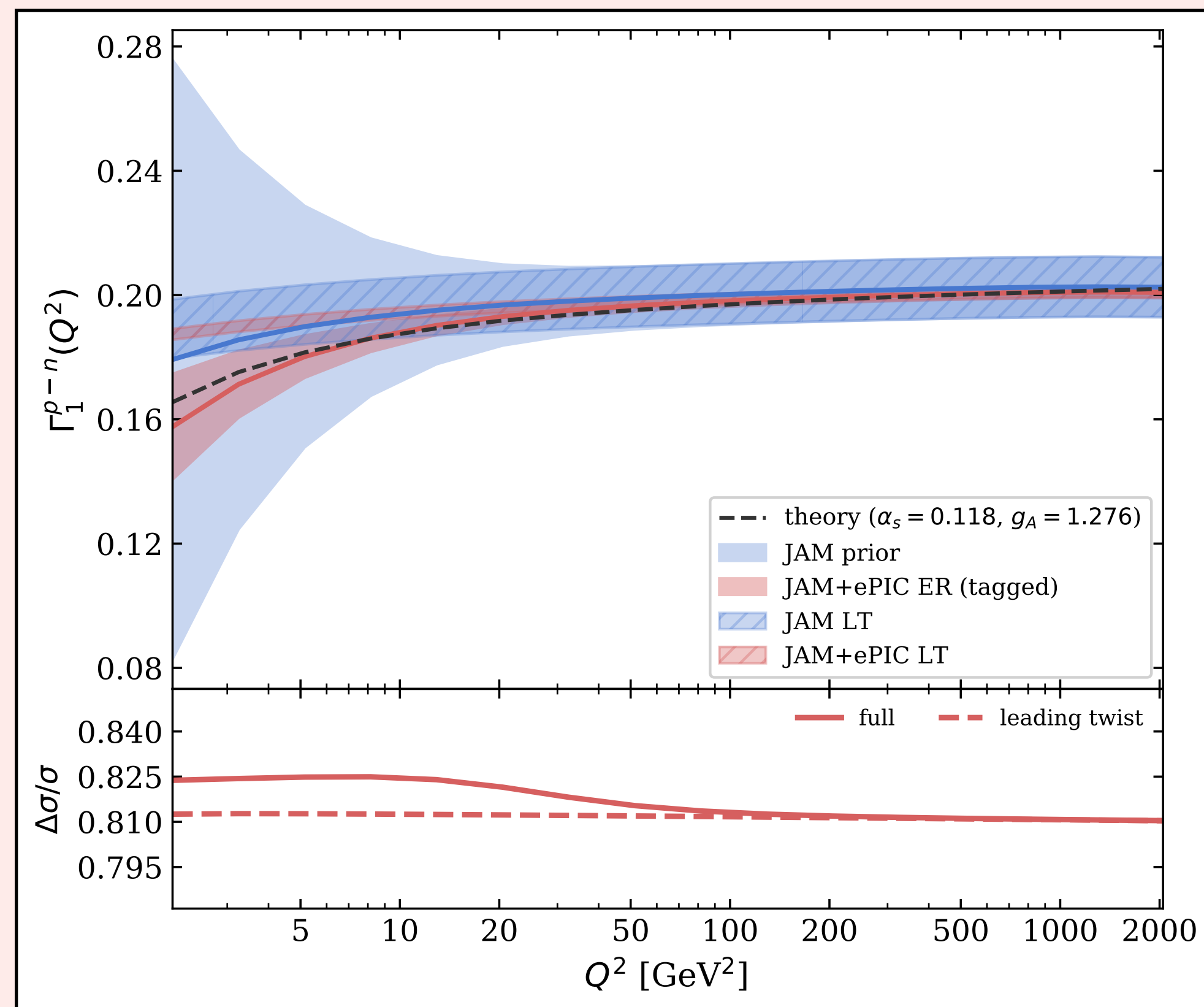
$$g_1 = \frac{F_2}{2x(1 + R)}(A_1 + \gamma A_2)$$

Spin structure functions



The Bjorken Sum Rule

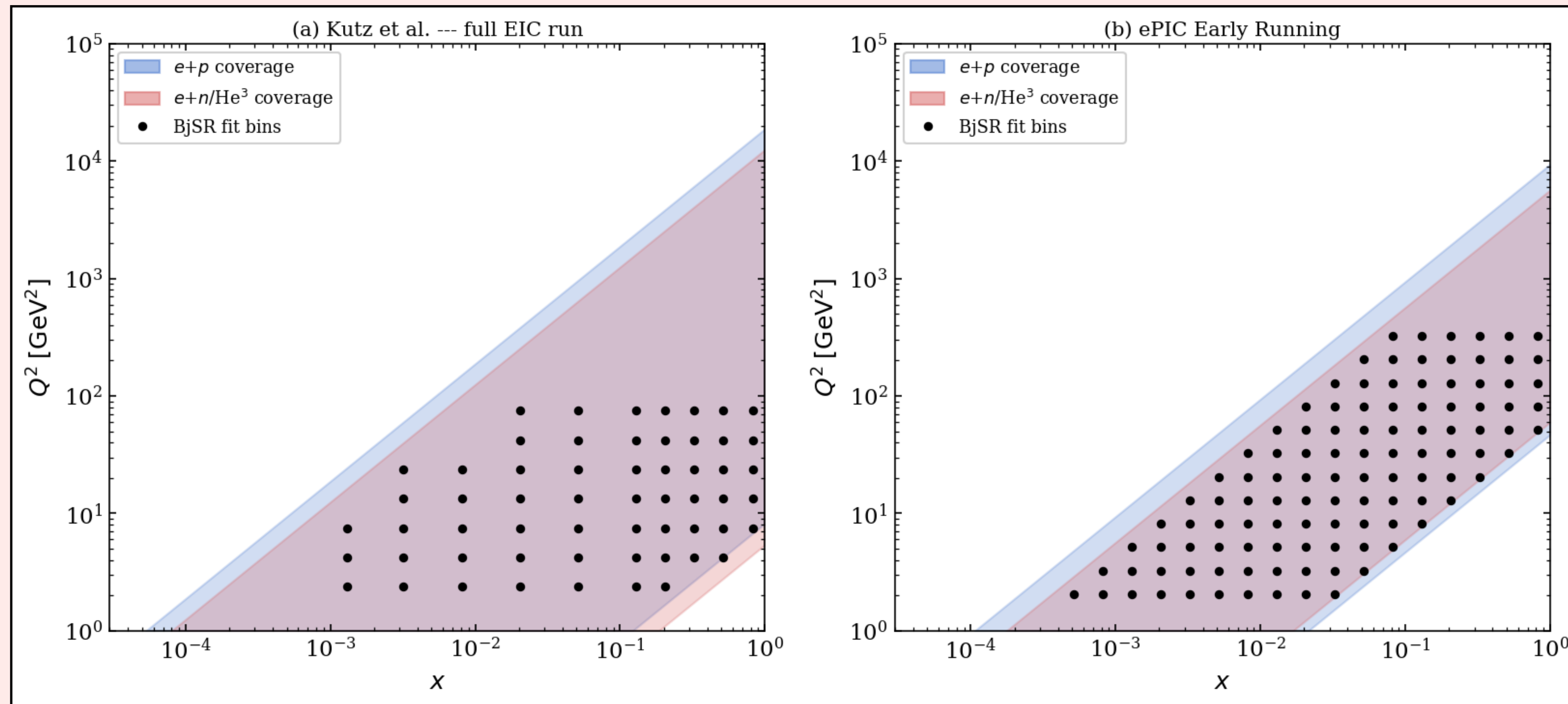
- At leading twist: $\Gamma_1^{p-n} \equiv \int_0^1 [g_1^p(x, Q^2) - g_1^n(x, Q^2)] dx = \frac{g_A}{6} C_{\text{ns}}(\alpha_s, Q^2)$
- N⁴LO: $C_{\text{ns}} = 1 - \frac{\alpha_s(Q^2)}{\pi} - 3.58 \left(\frac{\alpha_s(Q^2)}{\pi} \right)^2 - 20.22 \left(\frac{\alpha_s(Q^2)}{\pi} \right)^3 - 175.7 \left(\frac{\alpha_s(Q^2)}{\pi} \right)^4$



Assume all are $A_{\parallel}$ measurements:

- ep 9x275 GeV, 2.5 fb⁻¹
- ep 9x130 GeV, 1.0 fb⁻¹
- eHe3 9x166 GeV, 1.5 fb⁻¹, tagged

- ▶ Kutz et al. (2024) [10.1103/PhysRevD.110.074004](https://arxiv.org/abs/10.1103/PhysRevD.110.074004): ECCE projection for full EIC running
- ▶ New fit follows the similar fitting procedures, but use JAM global analysis to model unmeasured regions and different uncertainty estimates



Bjorken sum construction

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Decompose the integral to three parts:

$$\Gamma_1^{p-n} = \underbrace{\int_0^{x_{\min}} (g_1^p - g_1^n) dx}_L + \underbrace{\int_{x_{\min}}^{x_{\max}} (g_1^p - g_1^n) dx}_W + \underbrace{\int_{x_{\max}}^1 (g_1^p - g_1^n) dx}_H$$

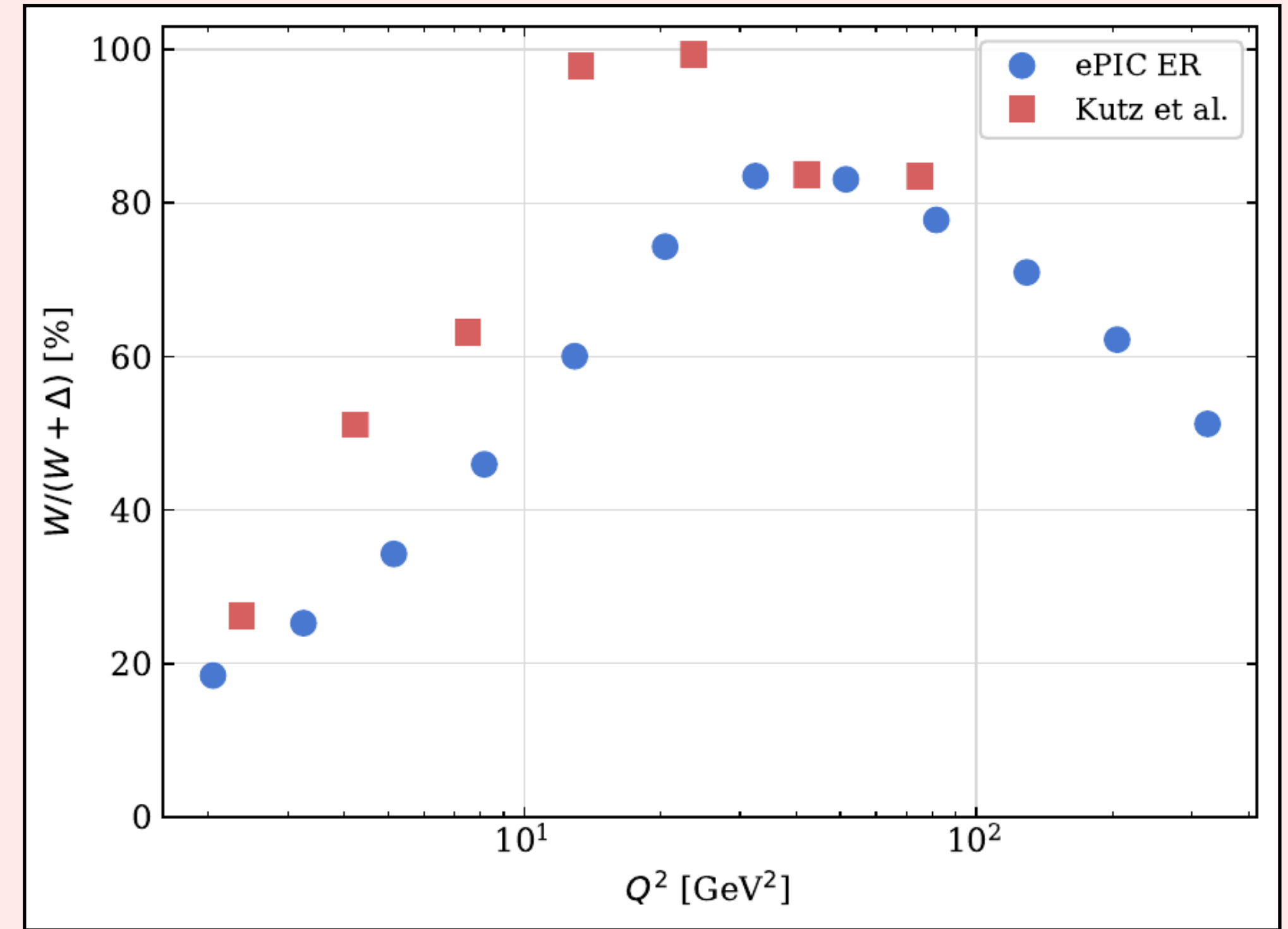
unmeasured low x measured region unmeasured high x

Kutz et al.

- W from ECCE full EIC running projection
- H from parameterizations of existing data
- L from N⁴LO Bjorken prediction at a reference α_s , by subtracting W+H; its uncertainty is estimated separately

New fit

- W from ePIC early running simulation
- $\Delta = L + H$ supplied by JAM replica ensemble, constrained by the JAM global analysis



Bjorken sum construction - uncertainty model

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New fit

- Build covariance matrix for data fluctuation

$$C_{\text{total}} = C_{\text{ePIC}} + C_{\text{completion}}$$

$$C_{\text{ePIC}} = \text{diag}(d_{\text{uncorr}}^2) + d_{\text{corr}} d_{\text{corr}}^T \text{ from } A_{\parallel} \text{ simulation}$$

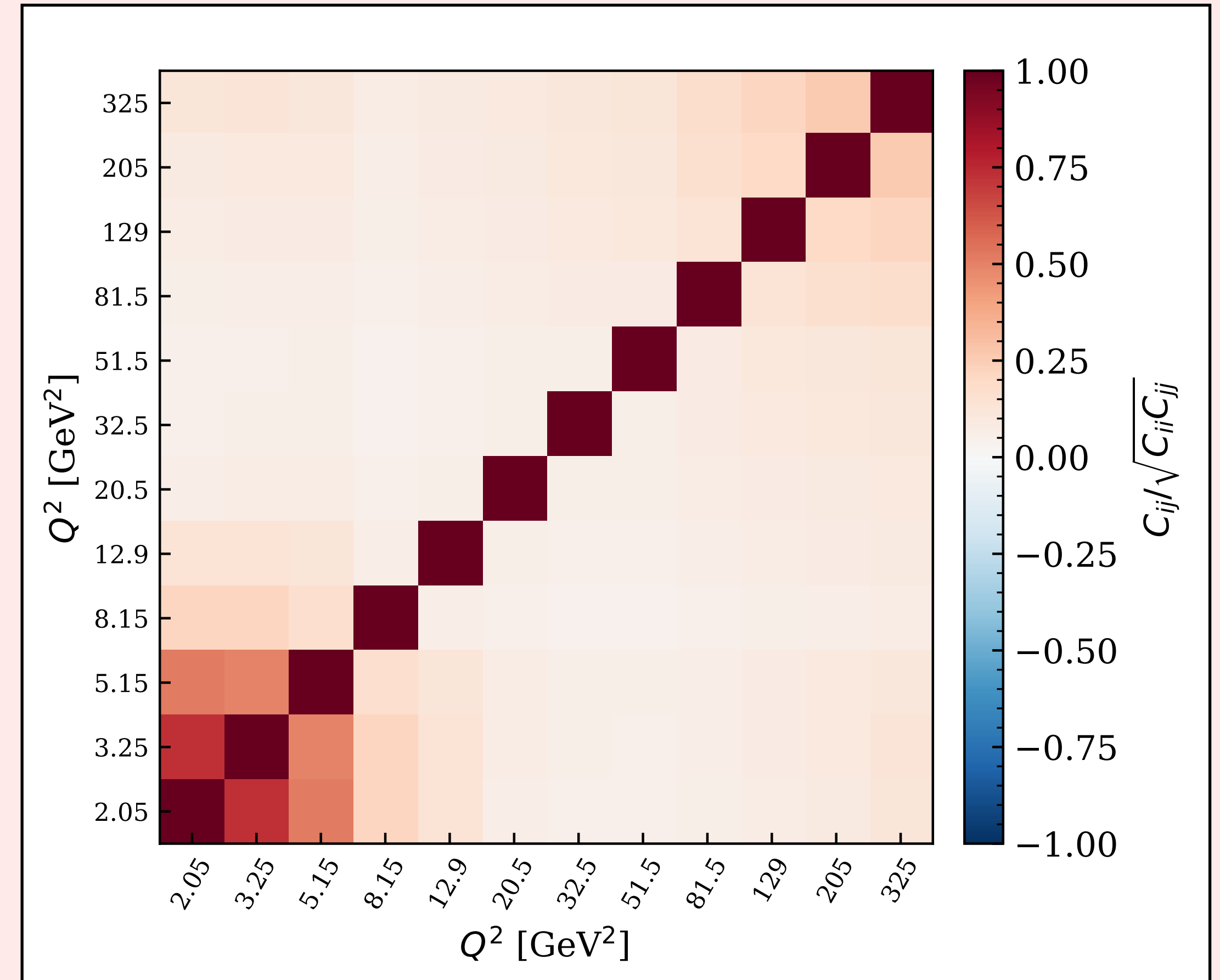
$$C_{\text{completion},ij} = \text{cov}_r \left(\Delta_r(Q_i^2), \Delta_r(Q_j^2) \right) \text{ from replica spread}$$

- Renormalization scale & HT uncertainty are examined later

Kutz et al.

- separate the projected uncertainty into several pieces:
 - Exp. uncorrelated unc. on the projected moments
 - beam-polarization uncertainty from pseudo experiments
 - low x and parameterization uncertainties
 - perturbative truncation uncertainty from the N⁴LO to N⁵LO shift
 - neglect higher-twist effects

Correlation matrix of the total projected $\Gamma_1^{p-n}(Q^2)$ covariance



$$C_{ij} = \delta_{ij} d_{\text{uncorr},i}^2 + d_{\text{corr},i} d_{\text{corr},j} + C_{\text{completion},ij}$$

Fitting mechanism

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- ▶ N⁴LO Bjorken coefficient function and five-loop QCD running with heavy-quark threshold crossings for the coupling
- ▶ Kutz et al.: fit Λ_s , convert to $\alpha_s(M_Z)$, neglect HT in the nominal high Q^2 fit
- ▶ New fit: fit $\alpha_s(M_Z)$ directly, include the JAM completion response, and test non-LT effects

$$\alpha_s(M_Z), g_A \longrightarrow \alpha_s(Q_i^2) \longrightarrow \Gamma_{i,LT}^{p-n} \longrightarrow \Gamma_{i,pred} \longrightarrow \chi^2$$

For each trial $\alpha_s(M_Z), g_A$, run the coupling to every Q_i^2 bin

Calculate N⁴LO Bjorken prediction, $\Gamma_{i,LT}^{p-n} = \frac{g_A}{6} C_{ns}(\alpha_s(Q_i^2))$

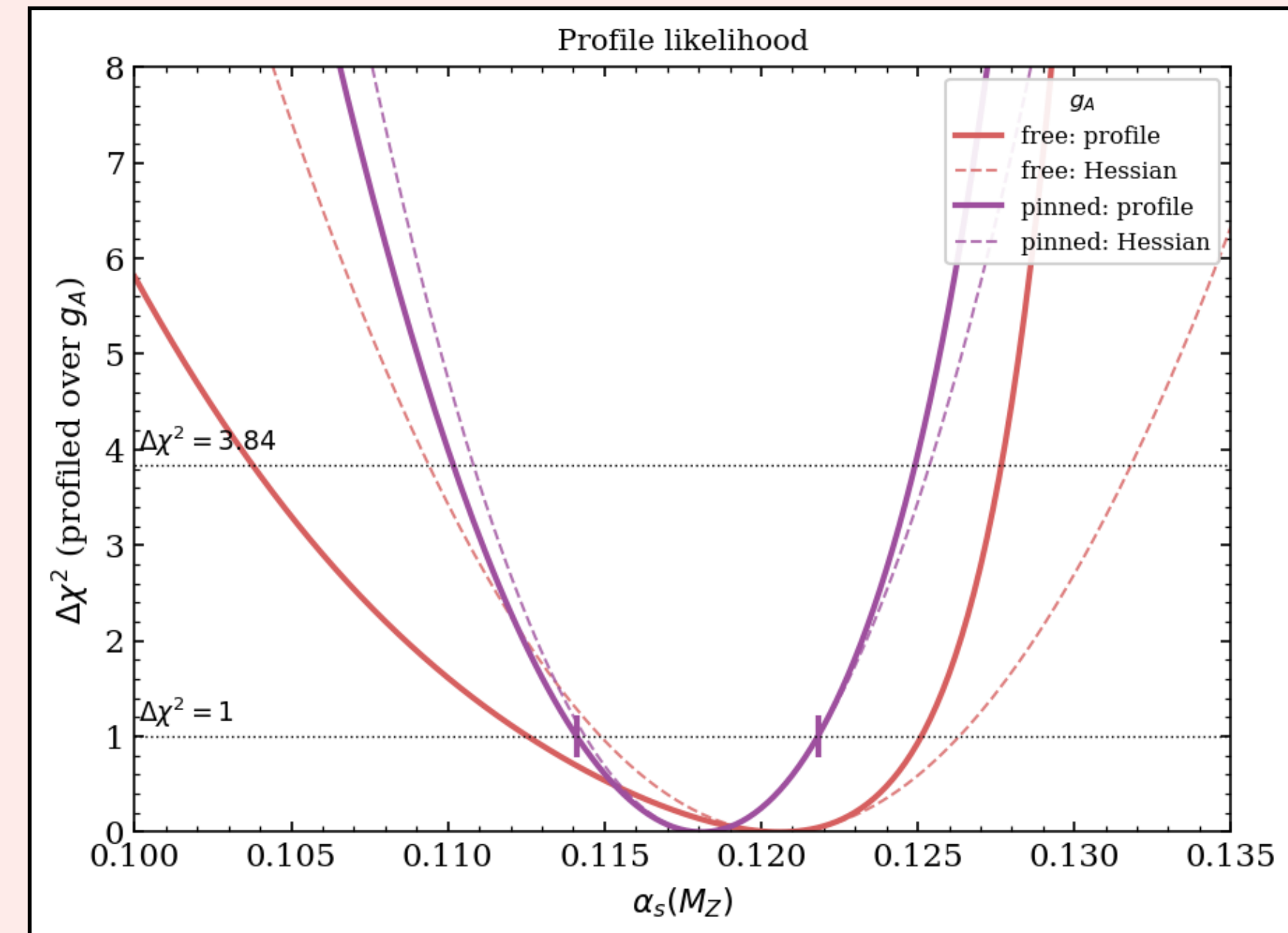
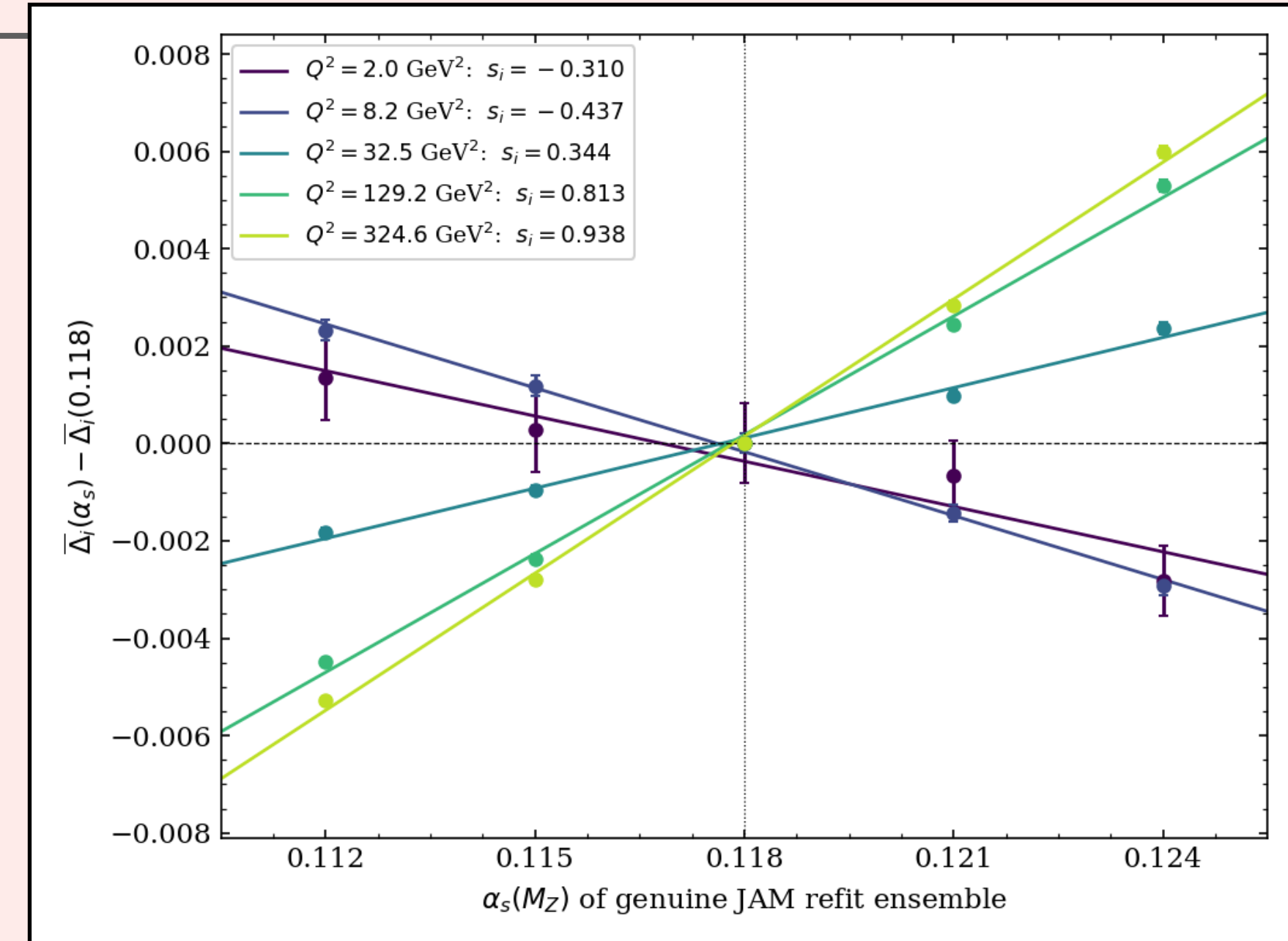
Add JAM completion response, $\Gamma_{i,pred} = \Gamma_{i,LT}^{p-n} - s_i [\alpha_s(M_Z) - 0.118]$

$s_i = \frac{d\bar{\Delta}_i}{d\alpha_s(M_Z)}$ slope from JAM refits at five different $\alpha_s(M_Z)$

compare prediction with projection point using the full covariance matrix,

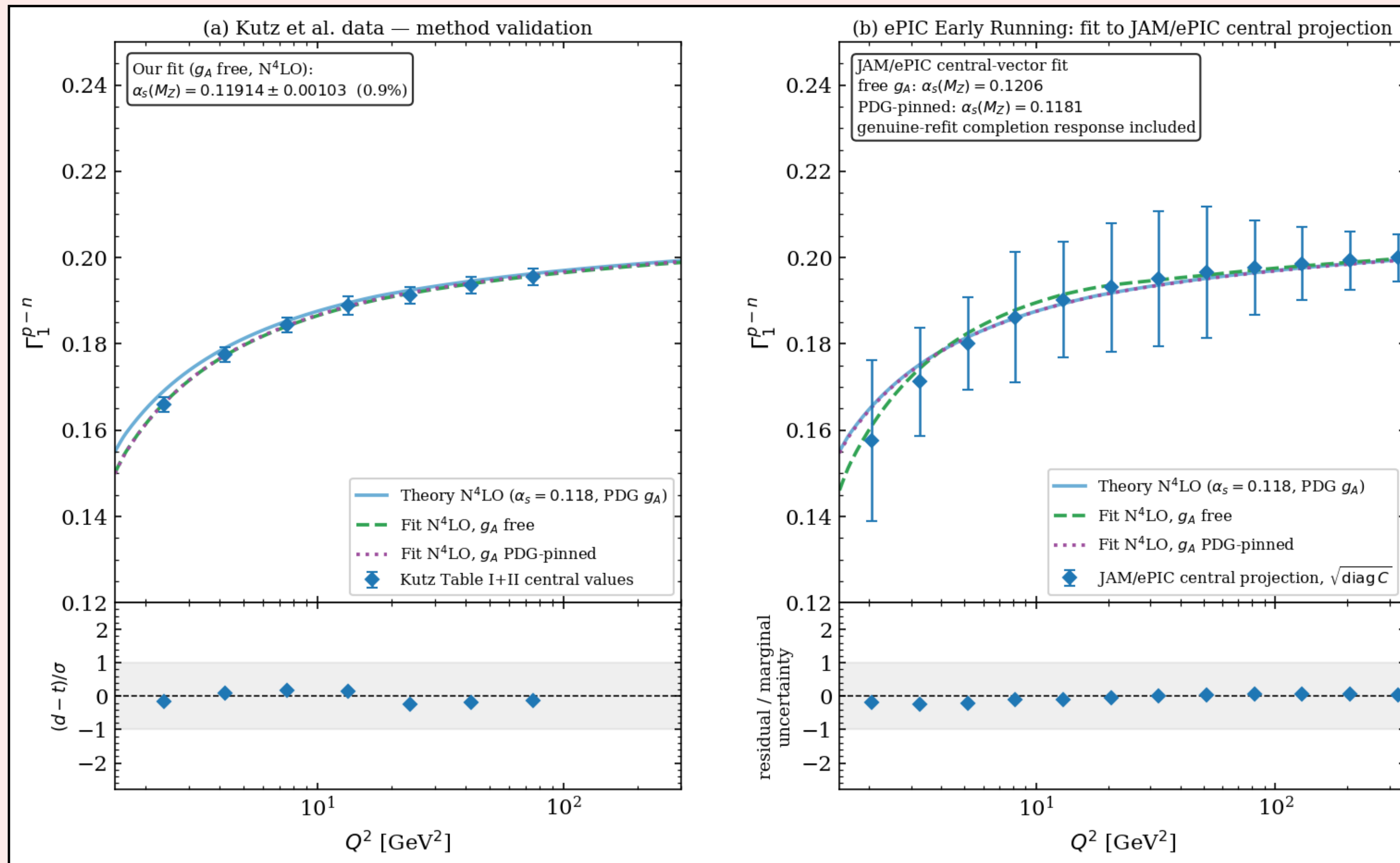
$$\chi^2 = (\Gamma_{\text{data}} - \Gamma_{\text{pred}})^T C^{-1} (\Gamma_{\text{data}} - \Gamma_{\text{pred}})$$

Minimize χ^2 and determine uncertainties from profile of $\alpha_s(M_Z)$



Fits to projected central moments

- ▶ N⁴LO Bjorken coefficient function and five-loop QCD running with heavy-quark threshold crossings for the coupling
- ▶ Kutz et al.: fit Λ_s , convert to $\alpha_s(M_Z)$, neglect HT in the nominal high Q^2 fit
- ▶ New fit: fit $\alpha_s(M_Z)$ directly, include the JAM completion response, and test non-LT effects because the fit extends to lower Q^2

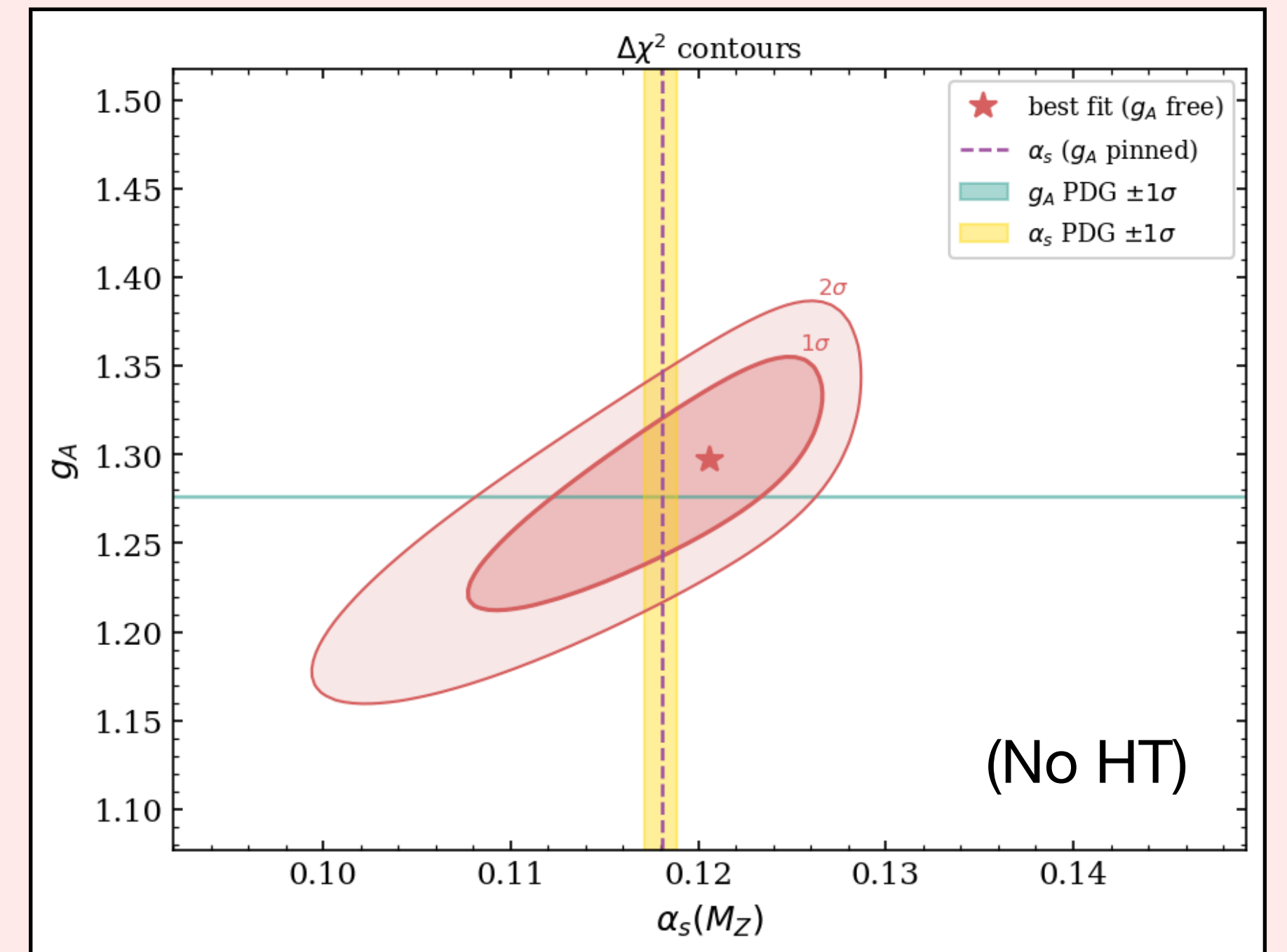
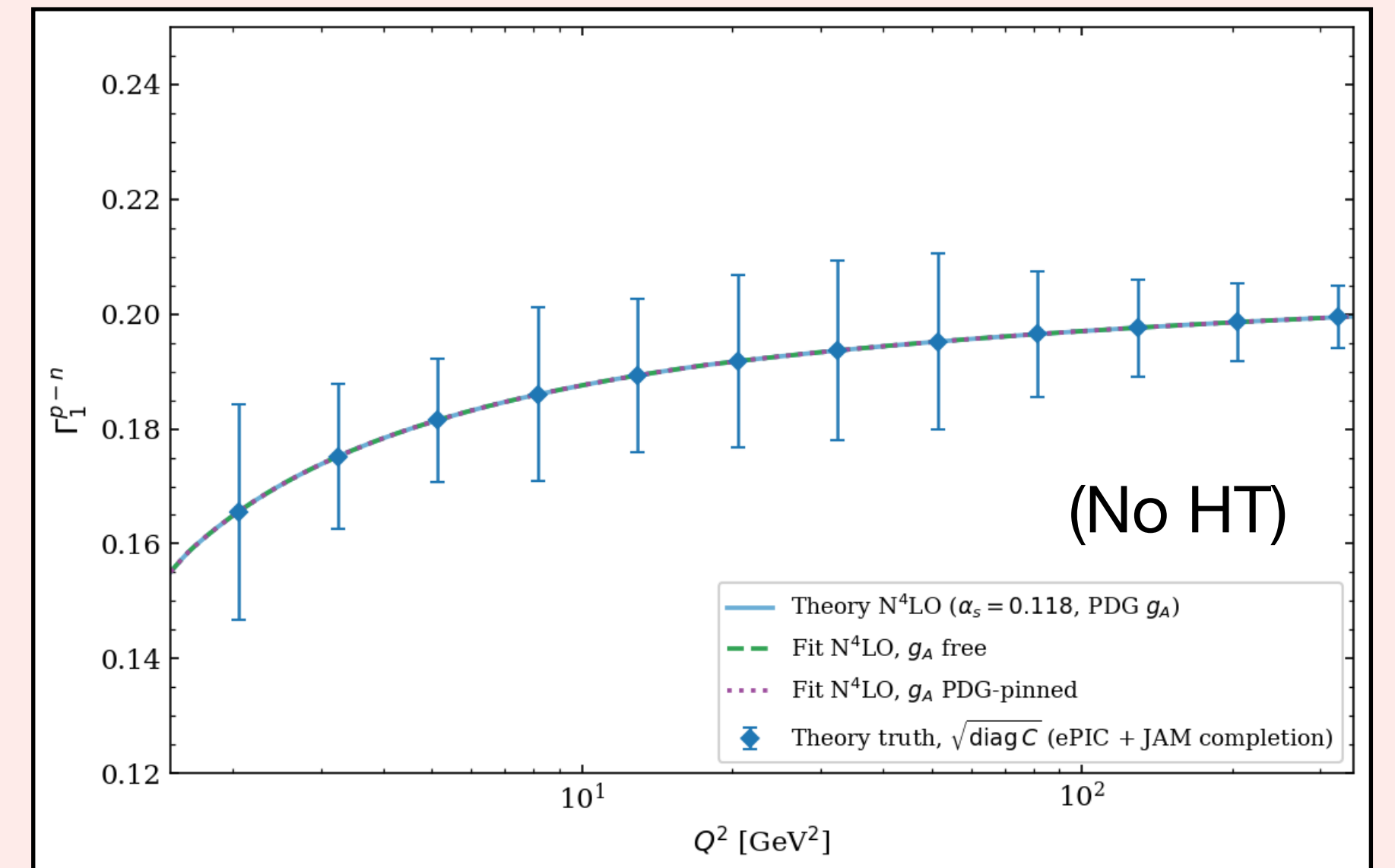


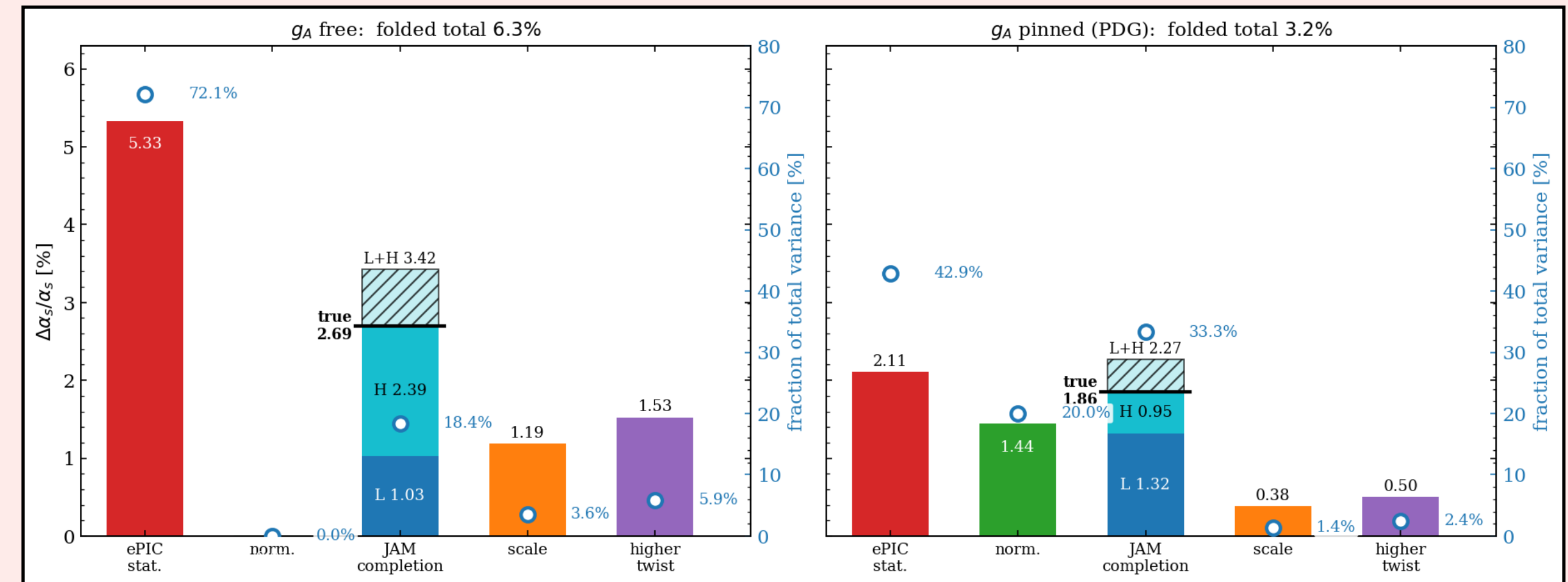
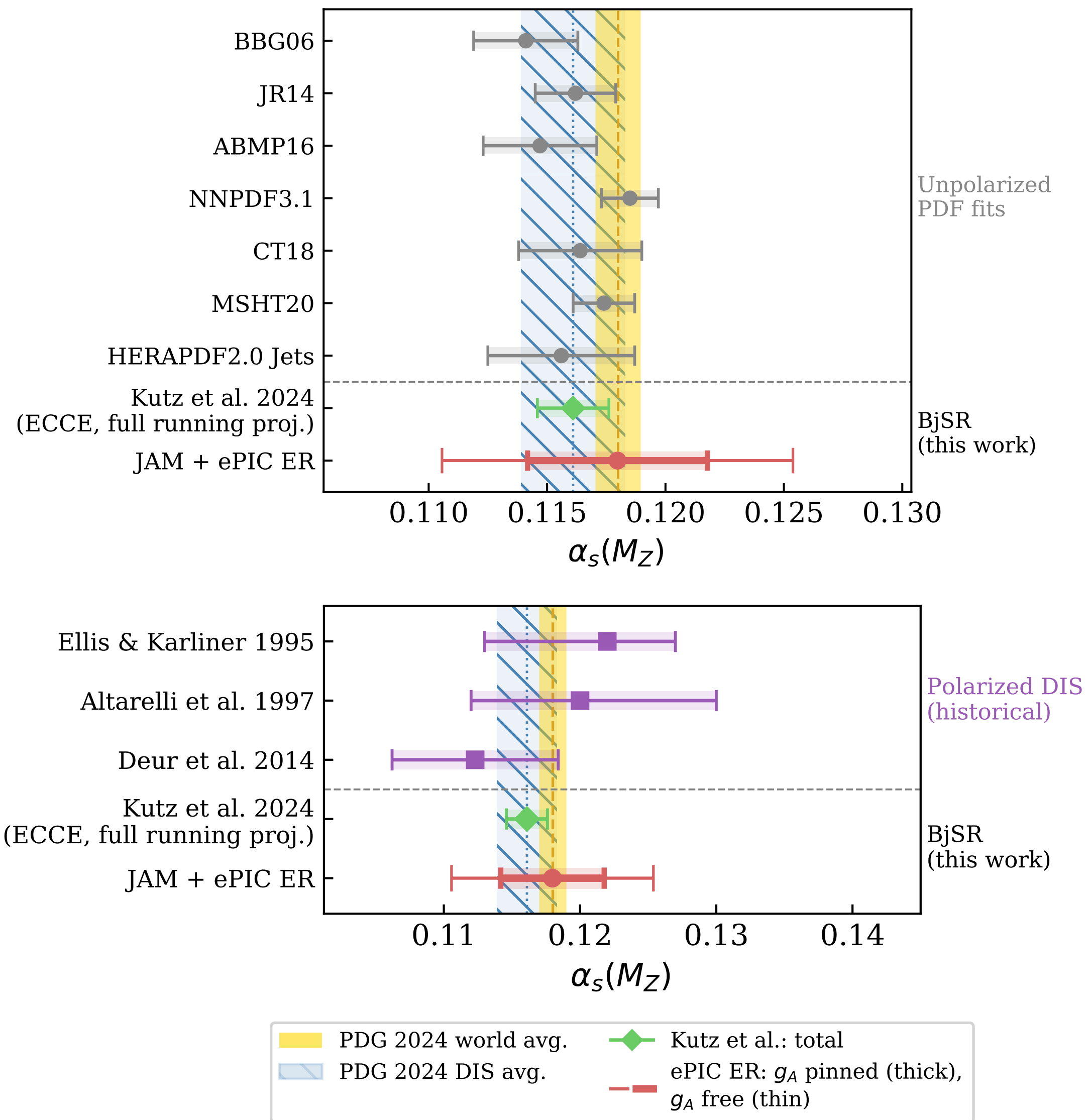
Expected sensitivity

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- ▶ Point centers are generated from $\alpha_s(M_Z) = 0.118$, $g_A = 1.2762$
- ▶ Same covariance $C = C_{\text{ePIC}} + C_{\text{completion}}$
- ▶ $\Gamma_{i,\text{pred}} = \Gamma_{i,\text{BjSR}}(\alpha_s, g_A) - s_i [\alpha_s(M_Z) - 0.118]$
- ▶ Repeat fits with renormalization-scale variations $Q^2/2$ and $2Q^2$
- ▶ Higher twist: fit $\mu_4/Q^2 + \mu_6/Q^4$ terms with Gaussian constraints derived from Deur et al. (arXiv:1405.7854), include uncertainty by marginalizing over μ_4, μ_6 .

Relative $\alpha_s(M_Z)$ uncertainty	g_A free	PDG-pinned g_A
Experimental + completion	5.98%	3.16%
Renormalization scale (half-spread)	1.19%	0.38%
Higher twist (width added by μ_4, μ_6 marginalization)	1.53%	0.50%
Folded total (higher twist marginalized + scale)	6.28%	3.22%
Folded total without higher twist	6.11%	3.19%





- ▶ Result reflects projected α_s precision with JAM model and ePIC early running data
- ▶ Projected precision improves on historical polarized DIS Bjorken extractions
- ▶ Early running data alone might not be competitive with existing world data
- ▶ Will repeat study for full running scenario, which should produce more competitive result as indicated by Kutz et al.
- ▶ World data fit? Polarized data & unpolarized data combined fit?