THE QCD PHASE DIAGRAM:
FROM THEORY TO EXPERIMENTAL SIGNATURES

Dalian, China
October 8 - 11, 2025

LEADING-ORDER QCD EOS IN STRONG MAGNETIC FIELDS AT NONZERO BARYON CHEMICAL POTENTIAL

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Based on *arXiv:2508.07532 [hep-lat]*
to soon appear in Phys. Rev. D. (accepted)

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Nuclear Science Computing Center at CCNU

Leading-Order QCD EoS in Strong Magnetic Fields at Nonzero Baryon Chemical Potential

QCD Equation of State

Equilibrium properties of strong interacting matter

$$p, \epsilon, \sigma, \ldots \equiv f(T, \mu, eB, \ldots)$$

thermodynamic obs. control parameters

Early Universe
energy, evolution → Friedmann eq.

Neutron Stars
mass-radii relations → TOV eq.

Heavy Ion-Collisions
QGP → hadronization → freeze-out

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QGP → hadronization → freeze-out

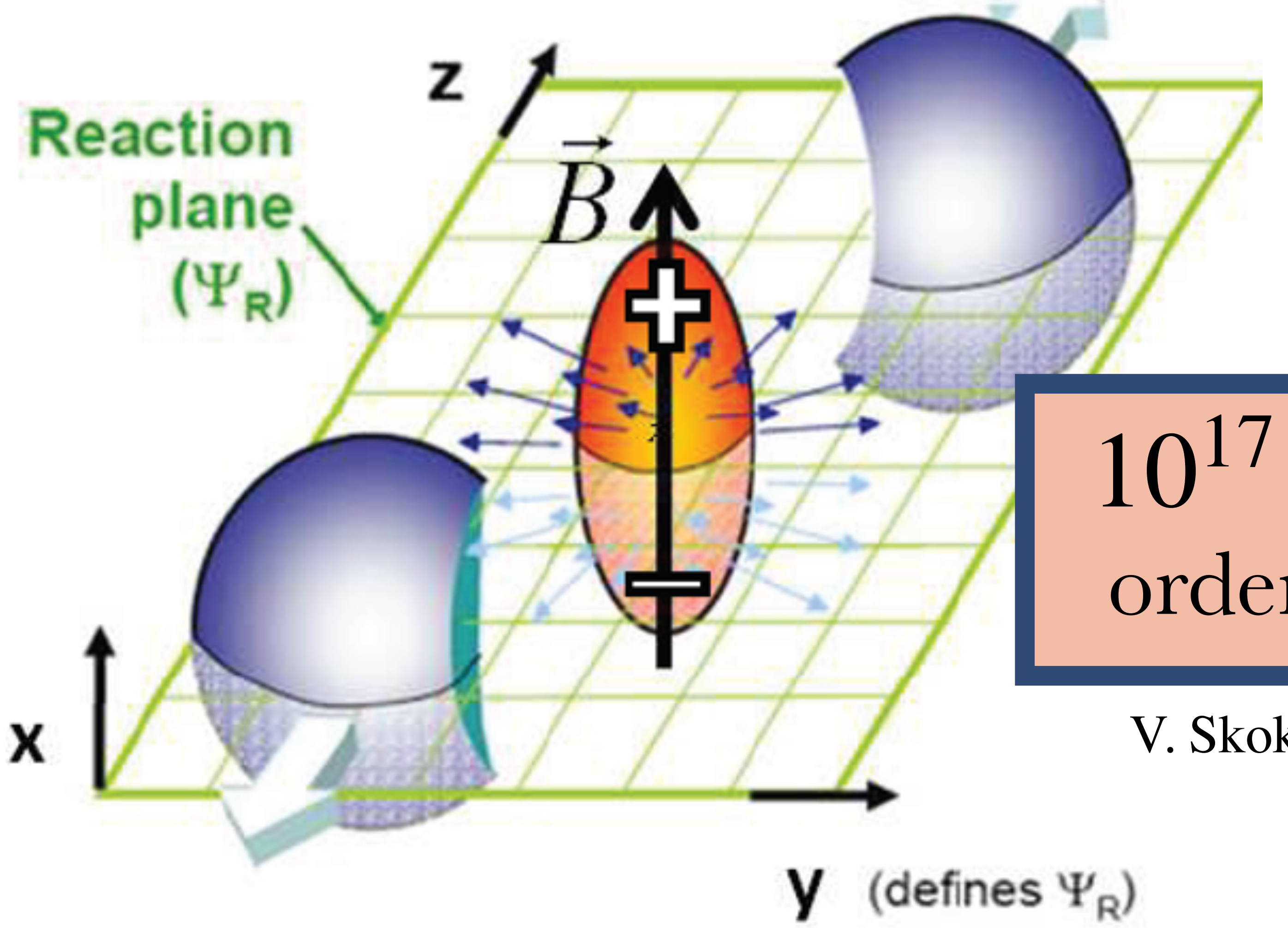
Strong Magnetic Fields

orders comparable to
intrinsic scales of interaction

(non-perturbative effects)

EoS in magnetic fields from Lattice QCD

J. Zhao, F. Wang, **PPNP** 107 (2019) 200-236



W.-T. Deng, X.-G. Huang
PRC 85 (2012) 044907

$10^{17} - 10^{18}$ G
orders of Λ_{QCD}^2

RHIC : $5m_\pi^2$
LHC : $70m_\pi^2$

V. Skokov, A. Illarionov, V. Toneev,
IJMPA 24 (2009) 5925

Leading-Order QCD EoS in Strong Magnetic Fields at Nonzero Baryon Chemical Potential

Finite-μ : **Sign-Problem in Lattice QCD** $\longrightarrow$ **Taylor Expand**

Pressure can be Taylor expanded as fluctuations of conserved charges $\mathscr{C} \in \{\mathrm{B}, \mathrm{Q}, \mathrm{S}\}$:

$$P(T, eB, \mu) \equiv \frac{P}{T^4} = \frac{1}{VT^3} \ln \mathscr{Z}_{\mathrm{GC}}(T, eB, V, \mu_{\mathscr{C}})$$

$$= \sum_{i,j,k=0}^{\infty} \frac{1}{i!j!k!} \boxed{\chi_{ijk}^{\mathrm{BQS}}} \mu_{\mathrm{B}}{}^{i} \mu_{\mathrm{Q}}{}^{j} \mu_{\mathrm{S}}{}^{k}$$

LO: $i + j + k = 2$

(Lattice computable & Experimentally measurable)

$$\chi_{ijk}^{\mathrm{BQS}} \equiv \chi_{ijk}^{\mathrm{BQS}}(T, eB) = \frac{\partial^{i+j+k}}{\partial\mu_{\mathrm{B}}^{i}\partial\mu_{\mathrm{Q}}^{j}\partial\mu_{\mathrm{S}}^{k}} P(T, eB, \mu)\Big|_{\mu=0}$$

$\mu_f \longleftrightarrow \mu_{\mathscr{C}}$ $\qquad$ $\chi_{ijk}^{uds} \longleftrightarrow \chi_{ijk}^{\mathrm{BQS}}$

(2+1)-f QCD

$$\mu_u = \frac{1}{3}\mu_{\mathrm{B}} + \frac{2}{3}\mu_{\mathrm{Q}}$$

$$\mu_d = \frac{1}{3}\mu_{\mathrm{B}} - \frac{1}{3}\mu_{\mathrm{Q}}$$

$$\mu_s = \frac{1}{3}\mu_{\mathrm{B}} - \frac{1}{3}\mu_{\mathrm{Q}} - \mu_{\mathrm{S}}$$

C. R. Allton, et.al, **PRD** 66 (2002), 074507

R. V. Gavai, S. Gupta, **PRD** 68 (2003), 034506

QCD EoS using fluctuations of conserved charges

Lattice (2+1)-f QCD Ingredients

- HISQ & Symanzik action with physical pion mass
- Lattice: $32^3 \times 8$, $48^3 \times 12 \rightarrow$ continuum estimates

Control parameter space:

- Temperature: focused around QCD transition

$$T \equiv [145 - 166)\ \text{MeV}$$

- Magnetic field (no sign-problem!)
  $\vec{B} = \vec{\nabla} \times \vec{A} \rightarrow$ Landau gauge: uniform B_z
  PBC + Stokes theorem $\rightarrow$ Quantization:

$$eB = 6\pi N_b / a^2 N_\sigma^2$$

M. D'Elia, S. Mukherjee, F. Sanfilippo, **PRD** 82 (2010), 051501

$$N_b = [1 - 32] \quad \rightarrow \quad eB \lesssim 0.8\ \text{GeV}^2 \sim 45 M_\pi^2$$

Nuclear Science Computing Center at CCNU

Jin-Biao Gu @ Thu, Oct 9

$$\chi_{ijk}^{\text{BQS}}$$

PHYSICAL REVIEW LETTERS **132,** 201903 (2024)

Baryon Electric Charge Correlation as a Magnetometer of QCD

H.-T. Ding, J.-B. Gu,* A. Kumar, S.-T. Li, and J.-H. Liu
Key Laboratory of Quark and Lepton Physics (MOE) and Institute of Particle Physics, Central China Normal University, Wuhan 430079, China

H.-T. Ding, J.-B. Gu, AK, S.-T. Li, J.-H. Liu, **PRL** 132 (2024) 201903

Thermodynamics

$$p, \epsilon, \sigma, \ldots \equiv f(\chi_{ijk}^{\text{BQS}}, T, eB, \boxed{\mu_{\text{B}}, \mu_{\text{Q}}, \mu_{\text{S}}, \ldots})$$

Strangeness Neutral : Initial Nuclei Conditions

$\neq (\mu_S = 0)$

$$P_2 \equiv \hat{p}_{\mathrm{LO}} = \frac{1}{2!}\left(\chi_2^{\mathrm{B}}\,\hat{\mu}_{\mathrm{B}}^2 + \chi_2^{\mathrm{Q}}\,\hat{\mu}_{\mathrm{Q}}^2 + \chi_2^{\mathrm{S}}\,\hat{\mu}_{\mathrm{S}}^2\right) + \chi_{11}^{\mathrm{BQ}}\,\hat{\mu}_{\mathrm{B}}\,\hat{\mu}_{\mathrm{Q}} + \chi_{11}^{\mathrm{BS}}\,\hat{\mu}_{\mathrm{B}}\,\hat{\mu}_{\mathrm{S}} + \chi_{11}^{\mathrm{QS}}\,\hat{\mu}_{\mathrm{Q}}\,\hat{\mu}_{\mathrm{S}}$$

Vanishing chemical potential

$$\hat{\mu}_{\mathrm{Q}} \equiv \hat{\mu}_{\mathrm{S}} = 0$$

$$P_2 \equiv \chi_2^{\mathrm{B}}/2$$

Strangeness neutrality : $n^{\mathrm{S}} = 0$ + Isospin asymmetry : $n^{\mathrm{Q}}/n^{\mathrm{B}} = r$

$\hat{\mu}_{\mathrm{Q/S}} \equiv \hat{\mu}_{\mathrm{Q/S}}(T, eB, \hat{\mu}_{\mathrm{B}})$

$q_{2k-1},\ s_{2k-1}$

$$\mu_{\mathrm{Q}}/\mu_{\mathrm{B}} = q_1 + q_3\hat{\mu}_{\mathrm{B}}^2 + \mathcal{O}(\hat{\mu}_{\mathrm{B}}^4) + \ldots$$

$$\mu_{\mathrm{S}}/\mu_{\mathrm{B}} = s_1 + s_3\hat{\mu}_{\mathrm{B}}^2 + \mathcal{O}(\hat{\mu}_{\mathrm{B}}^4) + \ldots$$

$(\mu_{\mathrm{Q}}/\mu_{\mathrm{B}})_{\mathrm{LO}}$

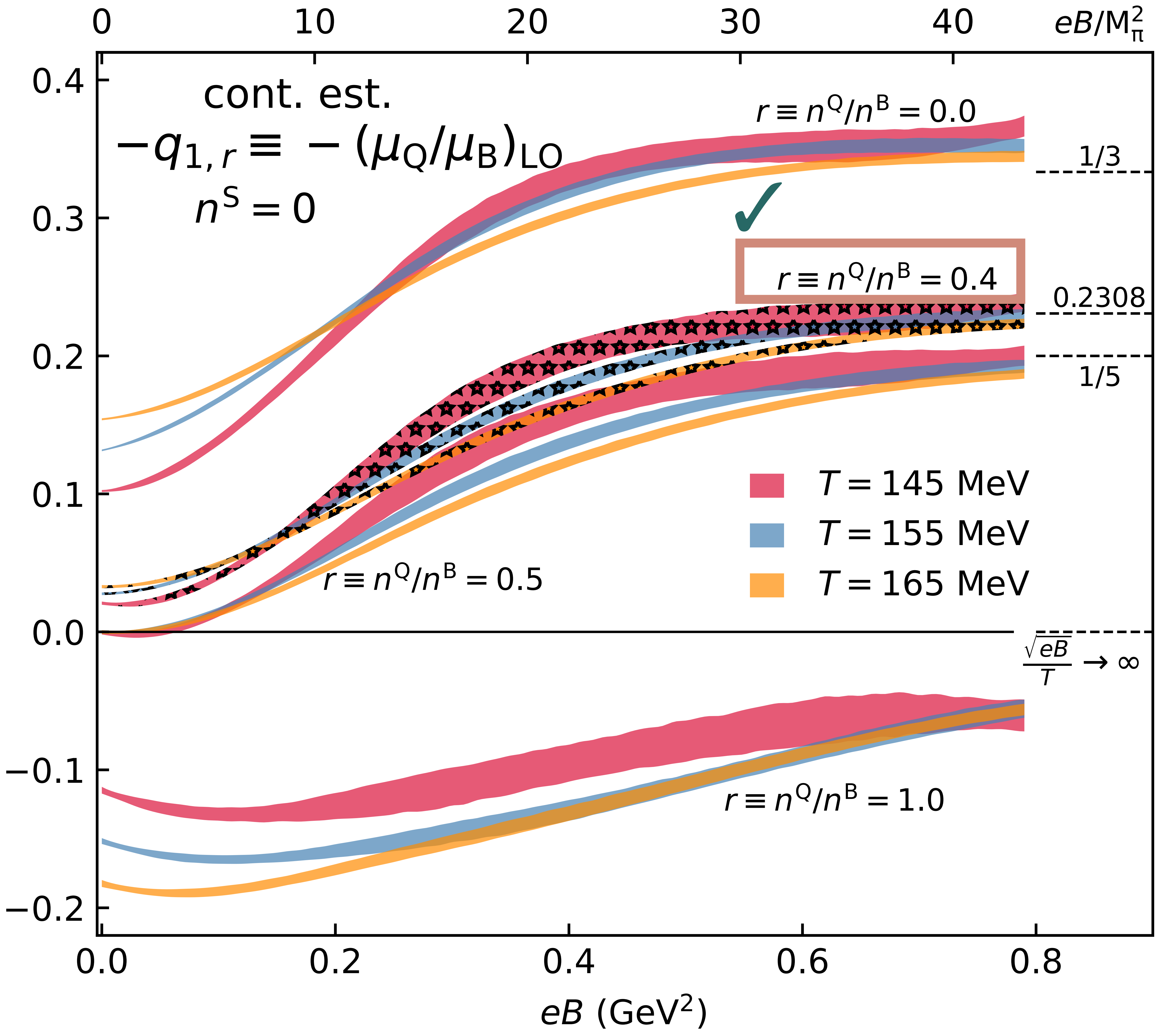
$$q_1 = \frac{r\left(\chi_2^{\mathrm{B}}\chi_2^{\mathrm{S}} - \chi_{11}^{\mathrm{BS}}\chi_{11}^{\mathrm{BS}}\right) - \left(\chi_{11}^{\mathrm{BQ}}\chi_2^{\mathrm{S}} - \chi_{11}^{\mathrm{BS}}\chi_{11}^{\mathrm{QS}}\right)}{\left(\chi_2^{\mathrm{Q}}\chi_2^{\mathrm{S}} - \chi_{11}^{\mathrm{QS}}\chi_{11}^{\mathrm{QS}}\right) - r\left(\chi_{11}^{\mathrm{BQ}}\chi_2^{\mathrm{S}} - \chi_{11}^{\mathrm{BS}}\chi_{11}^{\mathrm{QS}}\right)}$$

$(\mu_{\mathrm{S}}/\mu_{\mathrm{B}})_{\mathrm{LO}}$

$$s_1 = -\frac{\left(\chi_{11}^{\mathrm{BS}} + q_1\chi_{11}^{\mathrm{QS}}\right)}{\chi_2^{\mathrm{S}}}$$

HotQCD, **PRL** 109 (2012) 192302

$(\mu_Q/\mu_B)_{LO} \equiv q_1$: Strangeness Neutral Sys



H.-T. Ding, J.-B. Gu, A. Kumar, S.-T. Li, *arXiv:2508.07532 [hep-lat]*

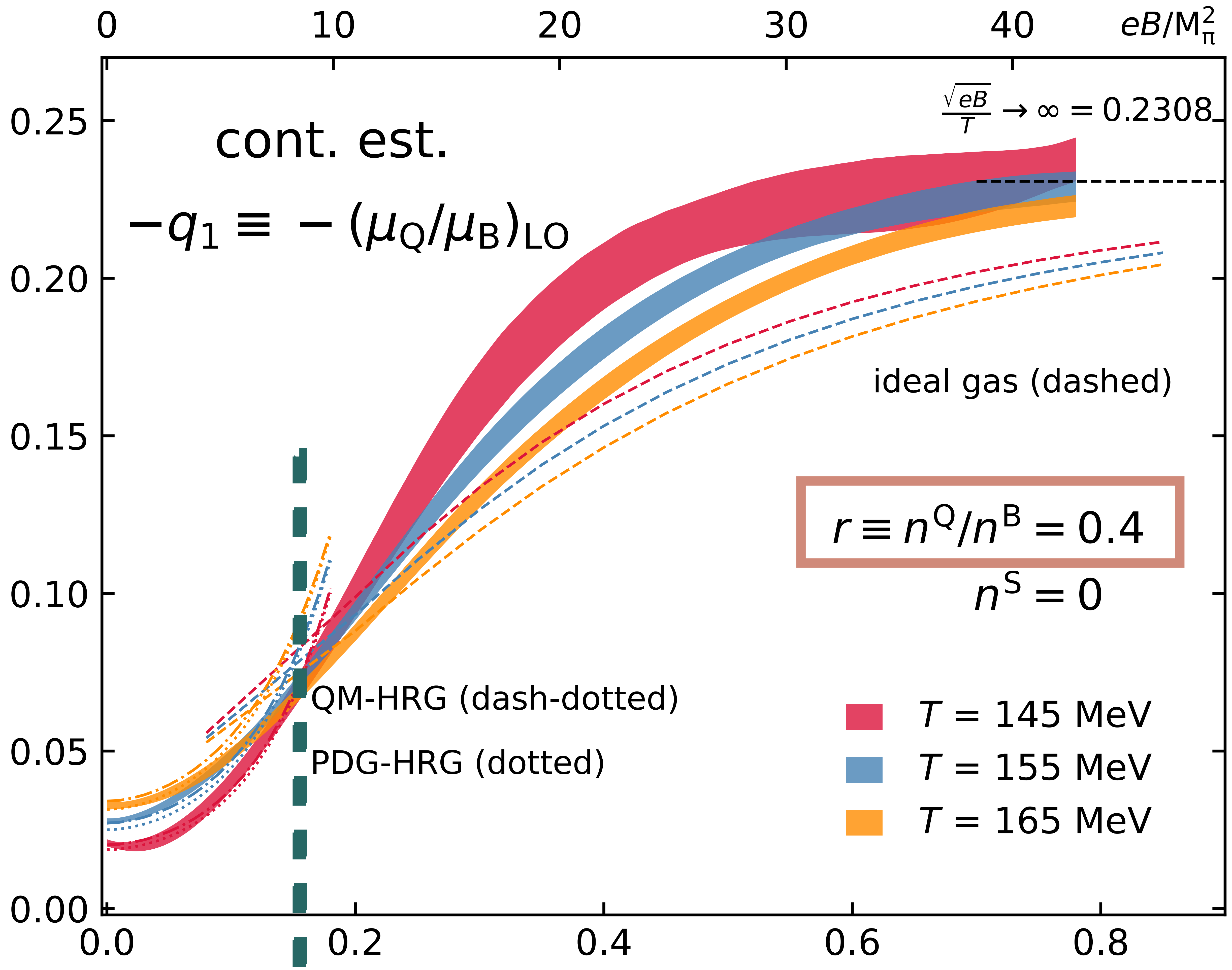
$$q_1 = \frac{r\left(\chi_2^B\chi_2^S - \chi_{11}^{BS}\chi_{11}^{BS}\right) - \left(\chi_{11}^{BQ}\chi_2^S - \chi_{11}^{BS}\chi_{11}^{QS}\right)}{\left(\chi_2^Q\chi_2^S - \chi_{11}^{QS}\chi_{11}^{QS}\right) - r\left(\chi_{11}^{BQ}\chi_2^S - \chi_{11}^{BS}\chi_{11}^{QS}\right)}$$

Isospin parameter

$r \equiv n^Q/n^B$ $[0,1]$

- 1.0 Maximal asymmetry positive charged $n^p \gg n^n \equiv 0$
- 1/2 Isospin symmetry $n^p = n^n$
- 0.4 Slight Isospin asymmetry $n^p < n^n$ — *Pb/Au* HIC — $\mu_Q < 0\big|_{\forall\, eB}$
- 0.0 Maximal asymmetry charge neutral $n^p \equiv 0 \ll n^n$

$(\mu_Q/\mu_B)_{LO} \equiv q_1$: Initial Pb–Nuclei Conditions



Weak-eB

H.-T. Ding, J.-B. Gu, A. Kumar, S.-T. Li, *arXiv:2508.07532 [hep-lat]*

- Negative! Further $-q_1$ as eB grows

Isospin asymmetry : $n^p < n^n \longrightarrow \mu_Q < 0\big|_{\forall\ eB}$

- Weak-eB : Lattice QCD and HRG agree

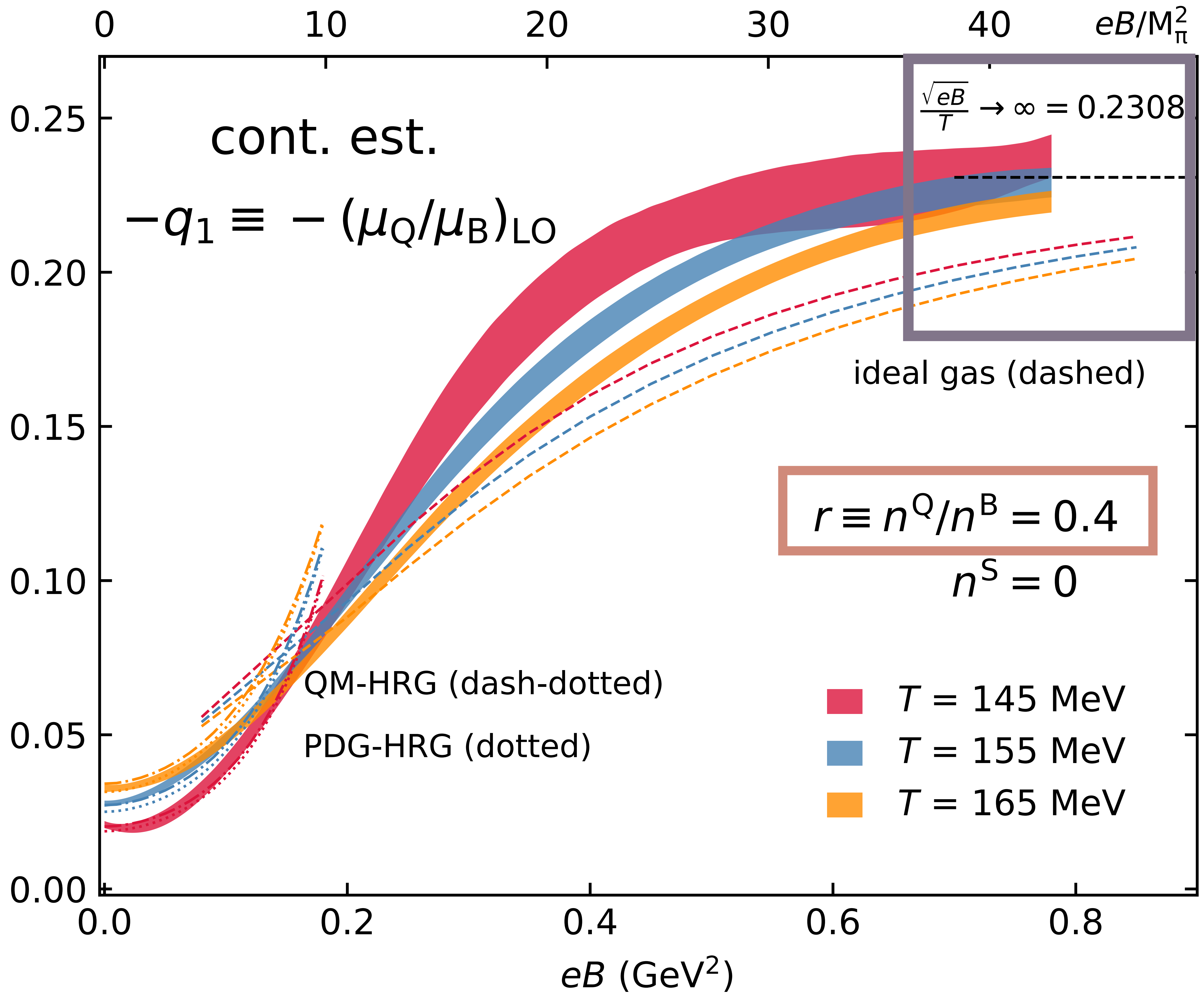
Enhanced degeneracy $\quad g_R \int \frac{d^3p}{(2\pi)^3} \xrightarrow{eB\ modified} \frac{|q_R|B}{2\pi} \sum_{s_z=-s_R}^{s_R} \sum_{l=0}^{\infty} \int \frac{dp_z}{2\pi}$

Lowered LLL energy $\quad E_R^c = \sqrt{m_R^2 + p_z^2 + 2|q_R|B(l + 1/2 - s_z)}$

K. Fukushima, Y. Hidaka, **PRL** 117 (2016), 102301
H.-T. Ding, S.-T. Li, Q. Shi, X.-D. Wang, **EPJA** 57 (2021) 6, 202

$(\mu_Q/\mu_B)_{LO} \equiv q_1$: Initial Pb–Nuclei Conditions

Strong-eB



H.-T. Ding, J.-B. Gu, A. Kumar, S.-T. Li, *arXiv:2508.07532 [hep-lat]*

$$q_1 = \frac{r\left(\chi_2^B\chi_2^S - \chi_{11}^{BS}\chi_{11}^{BS}\right) - \left(\chi_{11}^{BQ}\chi_2^S - \chi_{11}^{BS}\chi_{11}^{QS}\right)}{\left(\chi_2^Q\chi_2^S - \chi_{11}^{QS}\chi_{11}^{QS}\right) - r\left(\chi_{11}^{BQ}\chi_2^S - \chi_{11}^{BS}\chi_{11}^{QS}\right)}$$

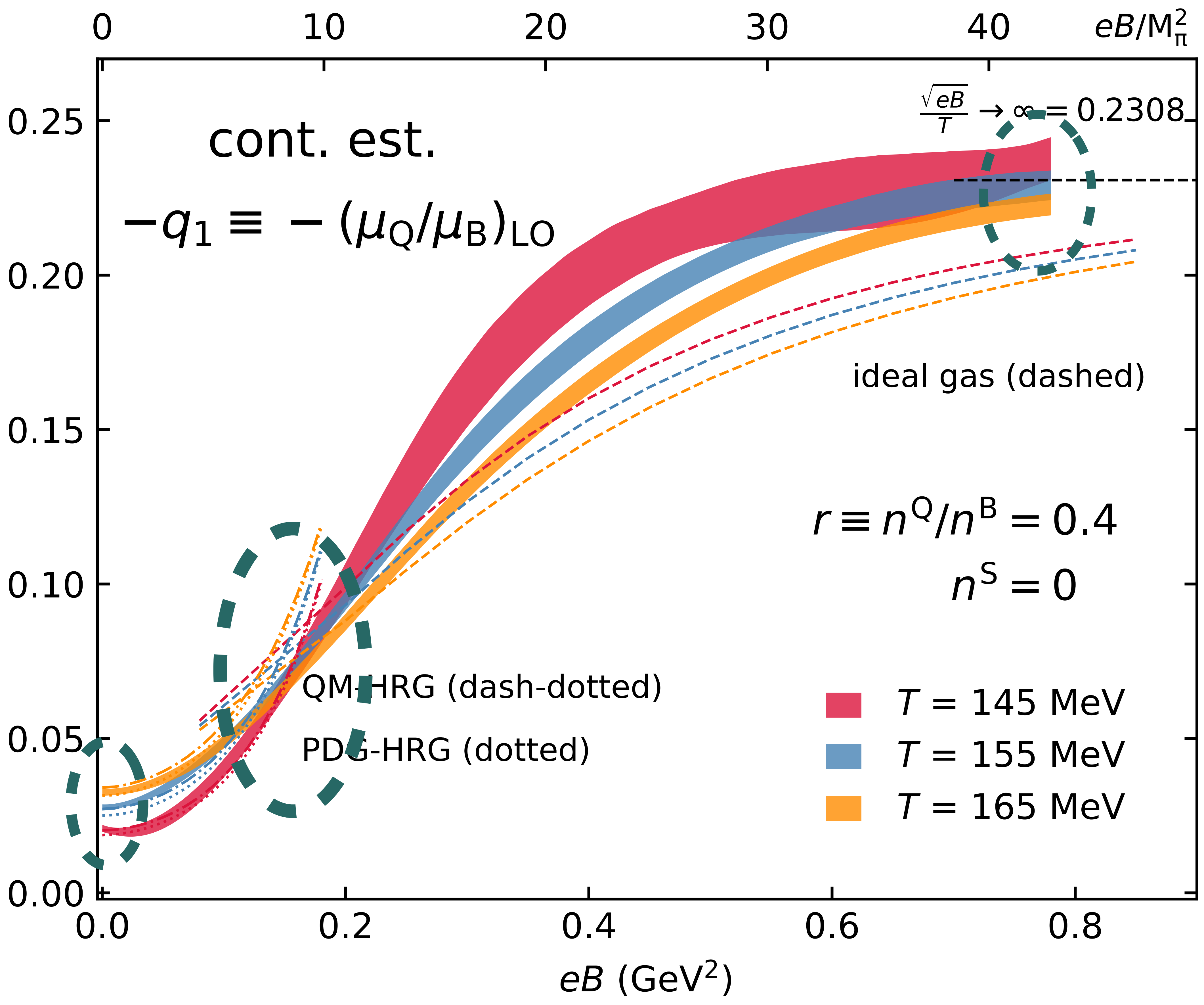
☑ Strong-eB: saturation to free limit

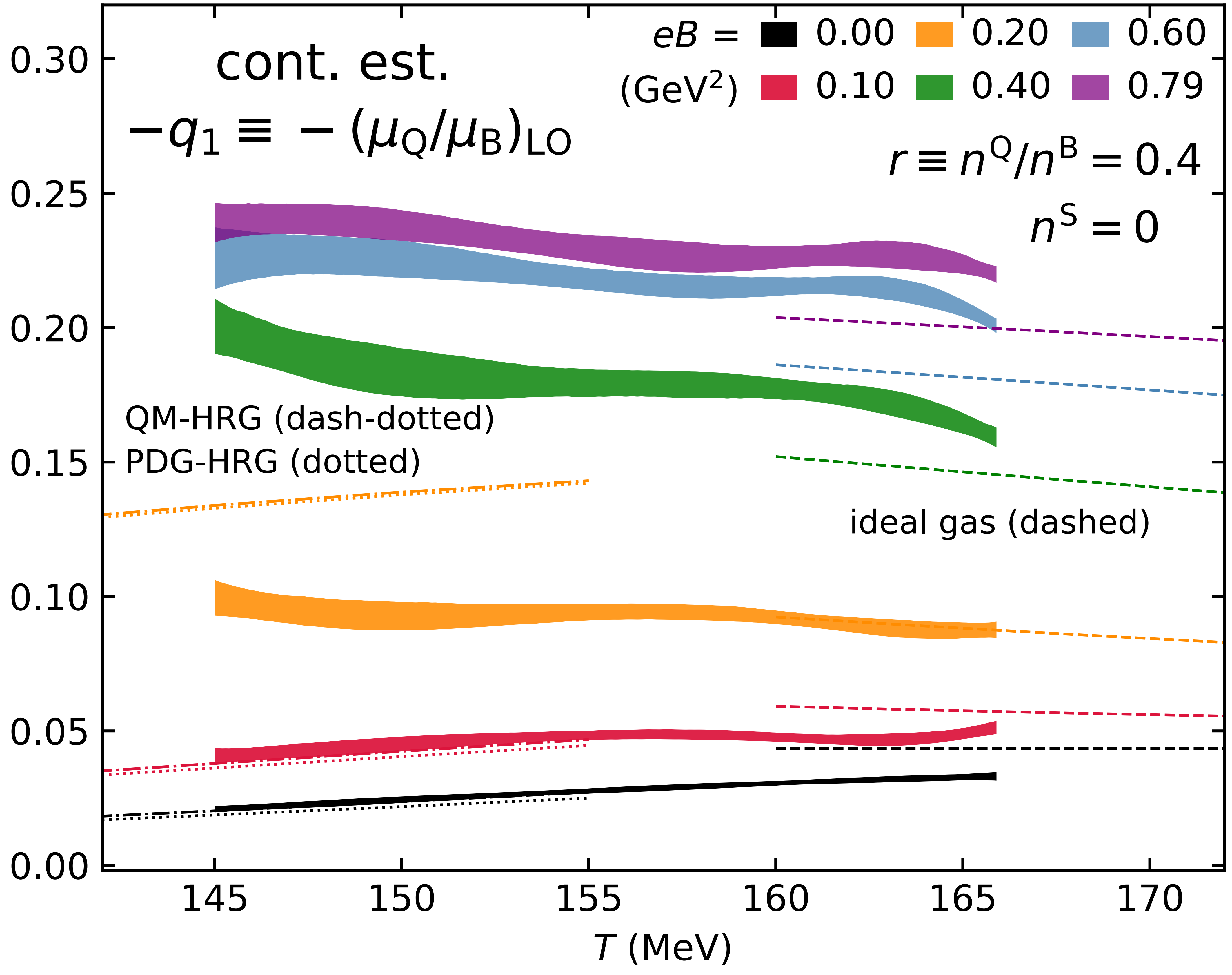
$$\sqrt{eB}/T \to \infty,\ T \to \infty$$

$$\frac{p_{\text{ideal}}}{T^4} = \frac{8\pi^2}{45} + \sum_f \frac{3|q_f|B}{\pi^2 T^2}\left[\frac{\pi^2}{12} + \underbrace{\boxed{\frac{\hat{\mu}_f^2}{4}}}_{\text{LLL}} + p_f^{ll}(B)\right]$$

H.-T. Ding, S.-T. Li, Q. Shi, X.-D. Wang, **EPJA** 57 (2021) 6, 202

$(\mu_Q/\mu_B)_{LO} \equiv q_1$: Initial $Pb-$Nuclei Conditions





vs-eB : Crossing among T-bands

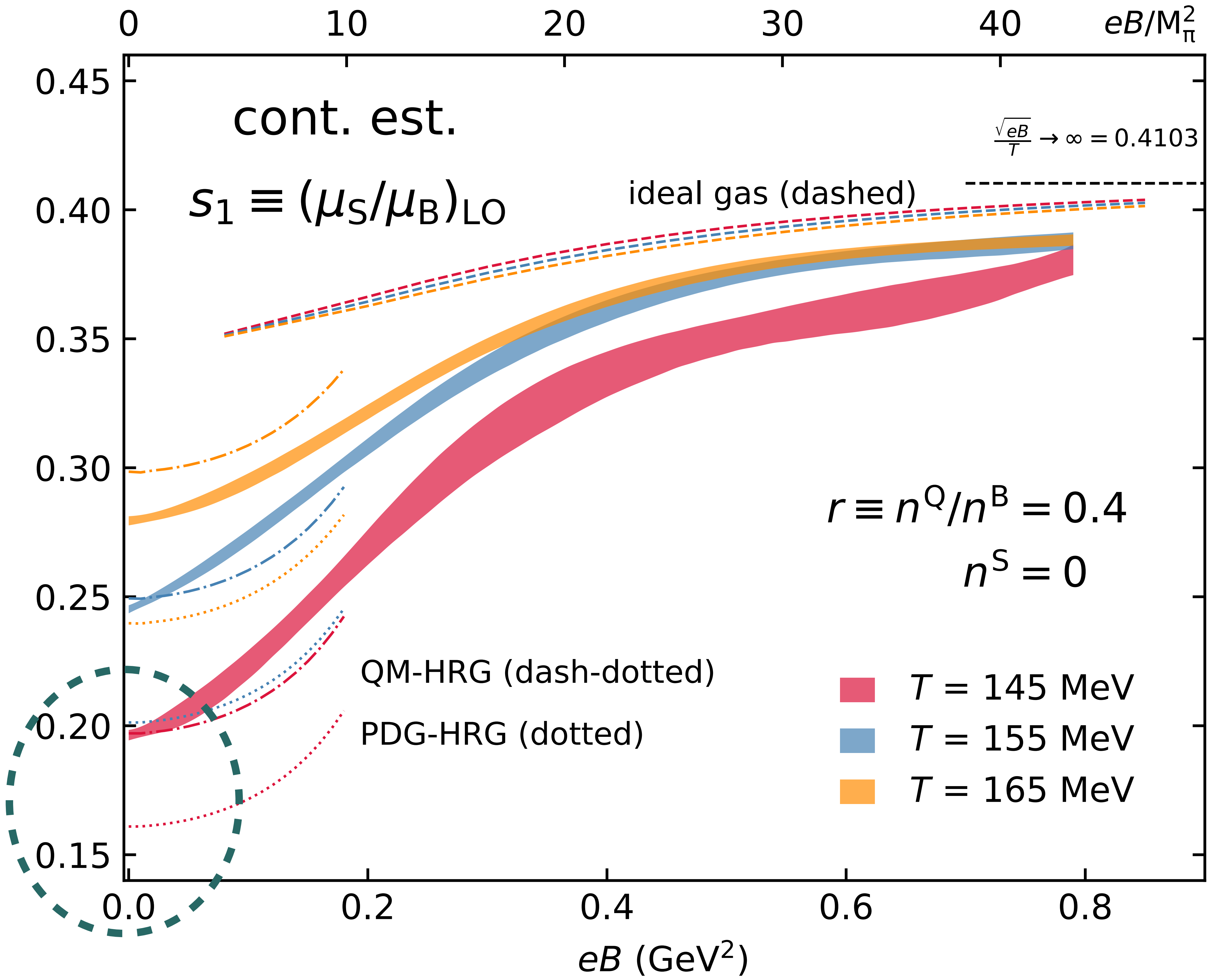
vs-T : Slope sign changes

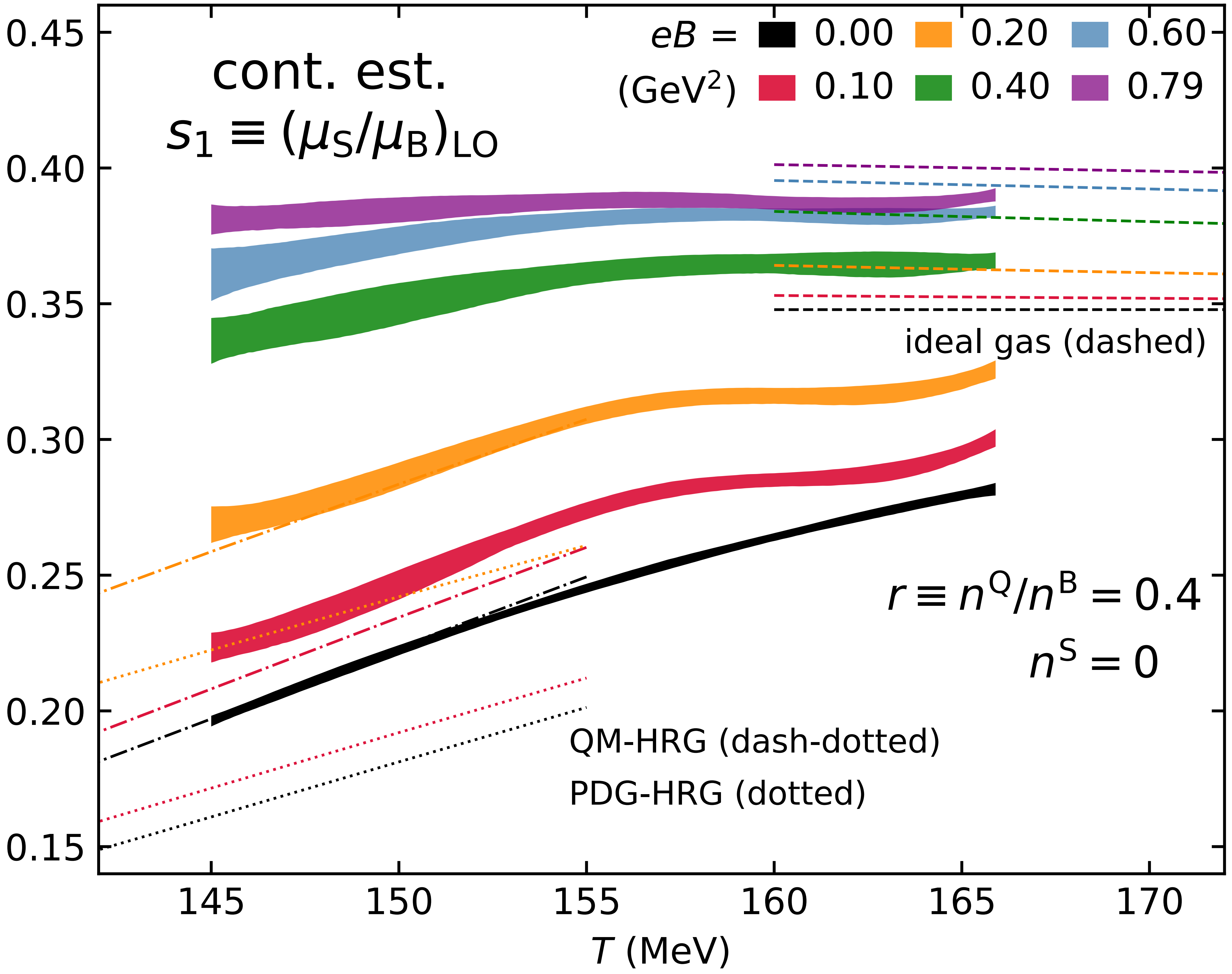
H.-T. Ding, J.-B. Gu, A. Kumar, S.-T. Li, *arXiv:2508.07532 [hep-lat]*

$(\mu_S/\mu_B)_{LO} \equiv s_1$: Initial Pb–Nuclei Conditions

$$s_1 = -\frac{\left(\chi_{11}^{BS} + q_1 \chi_{11}^{QS}\right)}{\chi_2^S}$$

- ☑ Positive s_1 and grows with eB. Indirect isospin asymmetry effects!
- ☑ Lattice results agreement better with QM-HRG than PDG-HRG





H.-T. Ding, J.-B. Gu, A. Kumar, S.-T. Li, *arXiv:2508.07532 [hep-lat]*

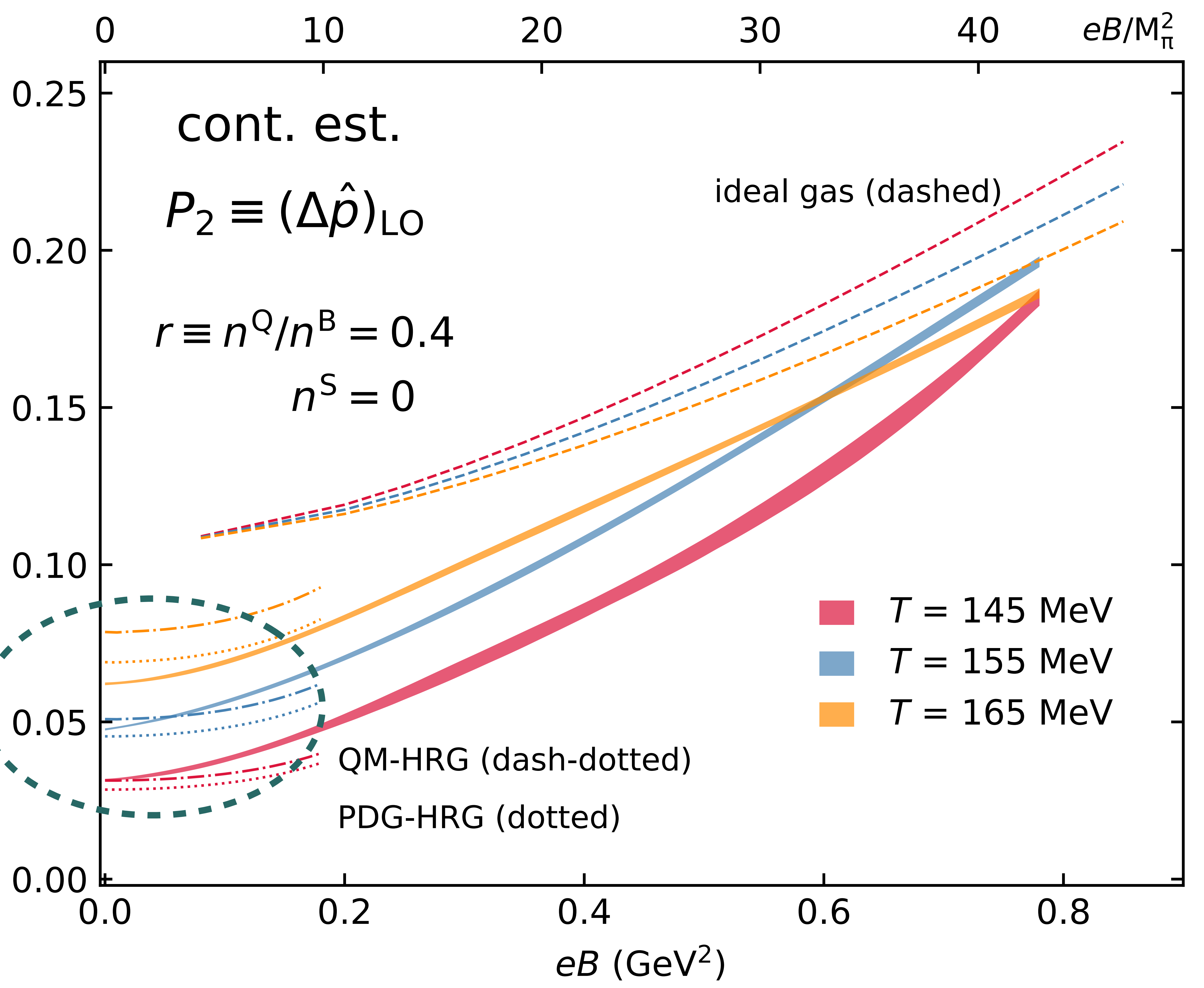
Pressure $\Delta\hat{p}_{\mathrm{LO}} \equiv P_2$: EoS in Magnetic Fields

$$\Delta\hat{p} \equiv \hat{p}(T, eB, \mu_{\mathrm{B}}) - \hat{p}(T, eB, 0) = \sum_{k=1}^{\infty} P_{2k}(T, eB)\, \hat{\mu}_{\mathrm{B}}^{2k}$$

$$P_2(T, eB) = \frac{1}{2}\left(\chi_2^{\mathrm{B}} + \chi_2^{\mathrm{Q}} q_1^2 + \chi_2^{\mathrm{S}} s_1^2\right) + \chi_{11}^{\mathrm{BQ}} q_1 + \chi_{11}^{\mathrm{BS}} s_1 + \chi_{11}^{\mathrm{QS}} q_1 s_1$$

- ☑ HRG agreement at weak-eB and low-T. P_2 increases as eB grows, more dominant contributions from LLL.

$$p^c_{R,\,\mathrm{HRG}} = \frac{|q_R| B}{(2\pi)^2 T^3} \sum_{s_z=-s_R}^{s_R} \sum_{l=0}^{\infty} \int_0^{\infty} dp_z \times \sum_{k=1}^{\infty} \frac{(\pm 1)^{k+1}}{k} e^{-k(E^c_R - \mu_R)/T}$$



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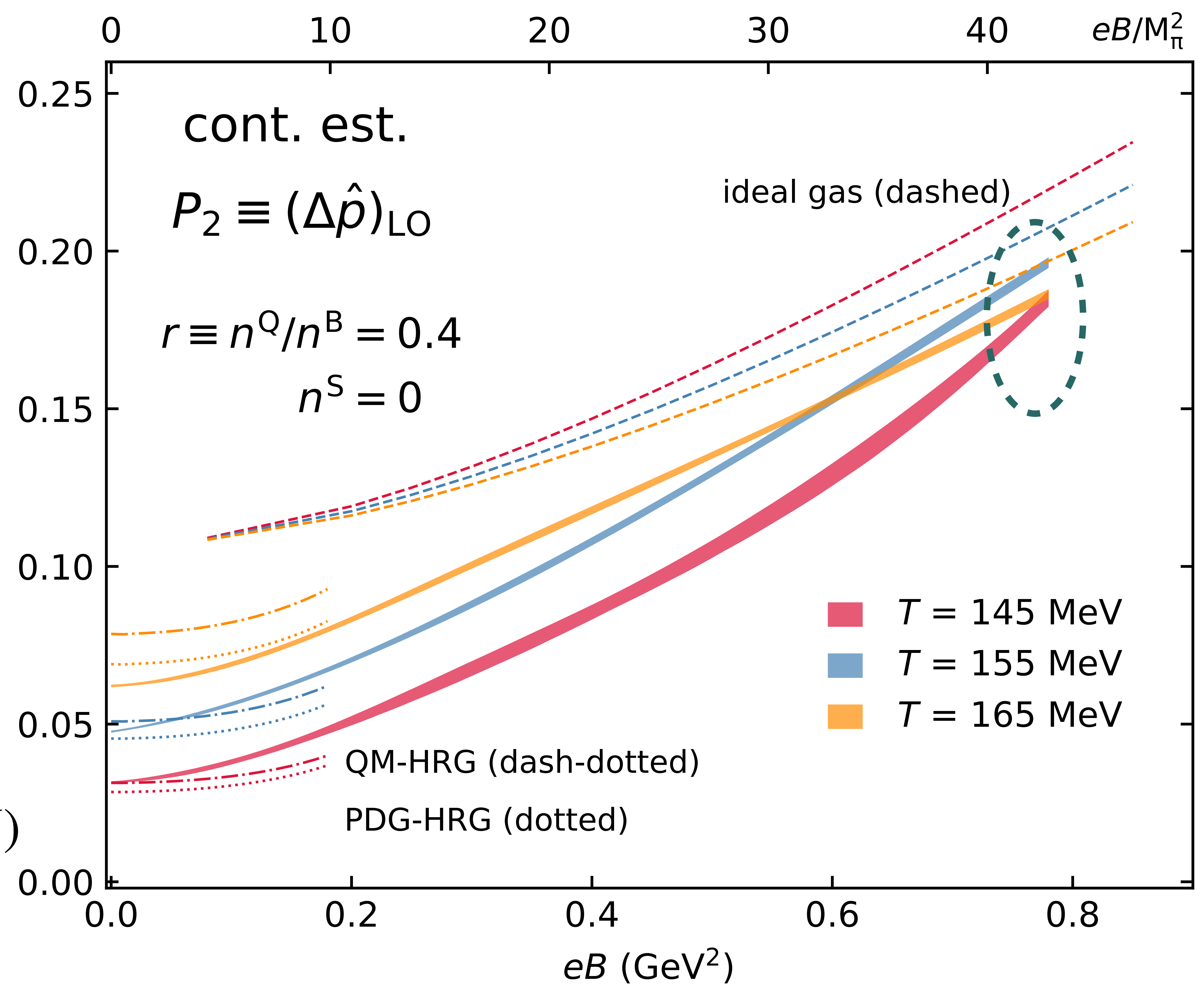
$$P_2(T, eB) = \frac{1}{2}\left(\chi_2^{\mathrm{B}} + \chi_2^{\mathrm{Q}} q_1^2 + \chi_2^{\mathrm{S}} s_1^2\right) + \chi_{11}^{\mathrm{BQ}} q_1 + \chi_{11}^{\mathrm{BS}} s_1 + \chi_{11}^{\mathrm{QS}} q_1 s_1$$

- ☑ HRG agreement at weak-eB and low-T. P_2 increases as eB grows, more dominant contributions from LLL.
- ☑ Strong-eB : Lattice results approach ideal gas but no saturation

	165	155	145 $\equiv T$ (MeV)
$\dfrac{P_2(T, eB \simeq 0.8\ \mathrm{GeV}^2)}{P_2(T, eB = 0)} \equiv$	~ 3	~ 4	~ 6



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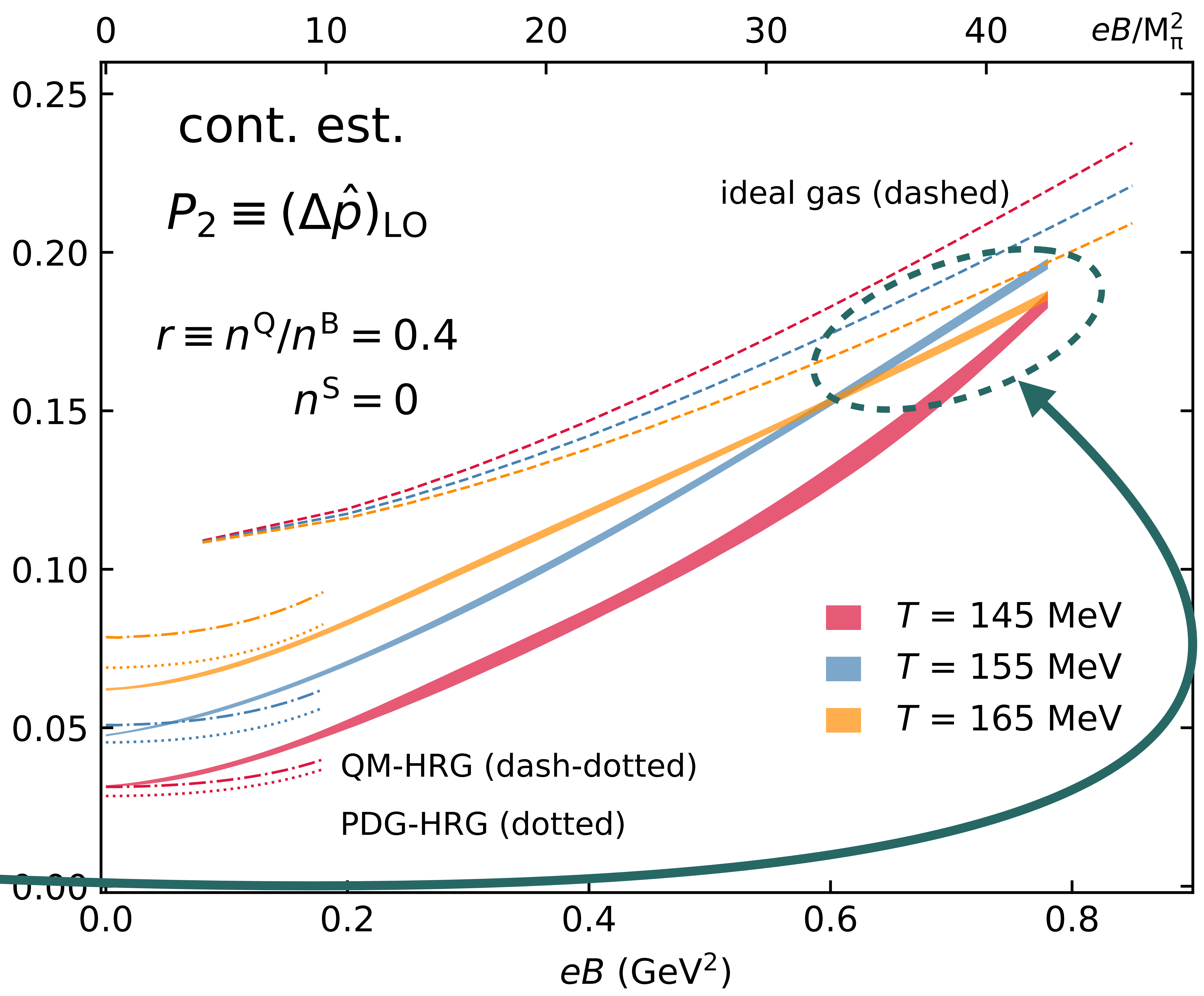
$$P_2(T, eB) = \frac{1}{2}\left(\chi_2^{\rm B} + \chi_2^{\rm Q} q_1^2 + \chi_2^{\rm S} s_1^2\right) + \chi_{11}^{\rm BQ} q_1 + \chi_{11}^{\rm BS} s_1 + \chi_{11}^{\rm QS} q_1 s_1$$

- HRG agreement at weak-eB and low-T. P_2 increases as eB grows, more dominant contributions from LLL.
- Strong-eB : Lattice results approach ideal gas but no saturation
- For $eB \gtrsim 0.6$ GeV^2: Crossings among T-bands



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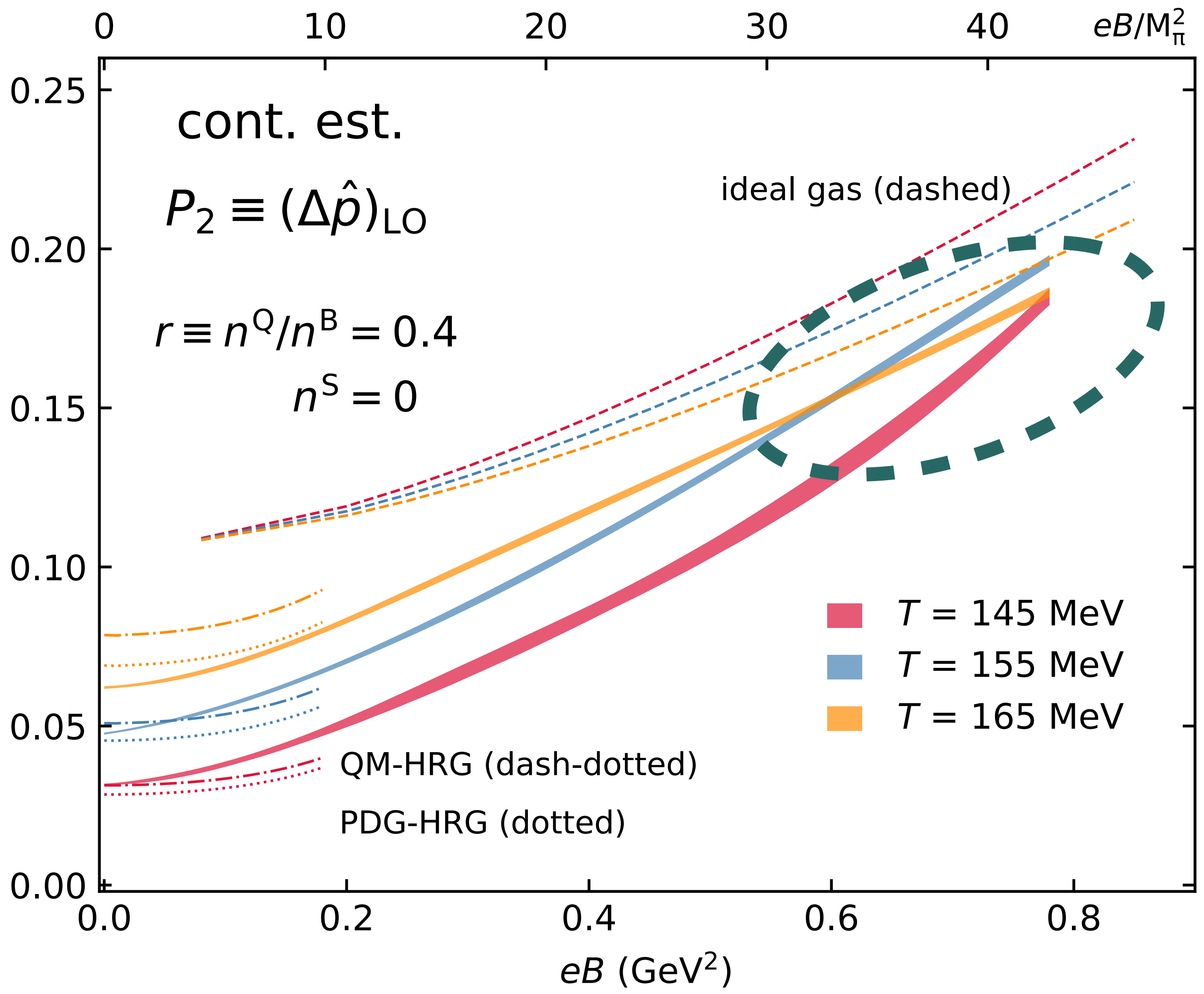
Pressure $\Delta\hat{p}_{\mathrm{LO}} \equiv P_2$: EoS in Magnetic Fields

☑ For $eB \gtrsim 0.6$ GeV^2 :

crossings among T-bands ⟷ non-monotonicity mild peak formation

☑ Peak structure shifts towards low-T : T_{pc}- lowering



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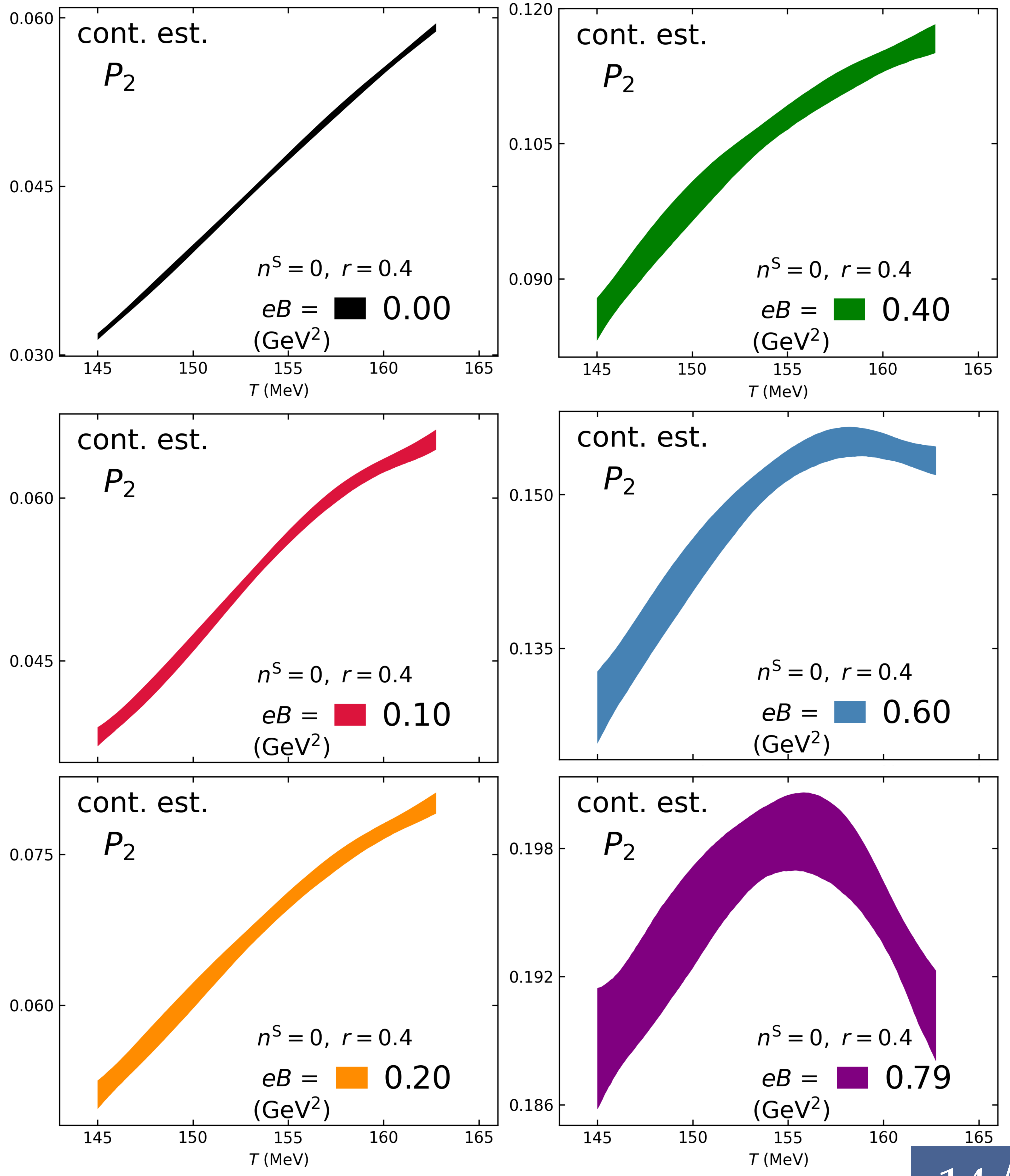
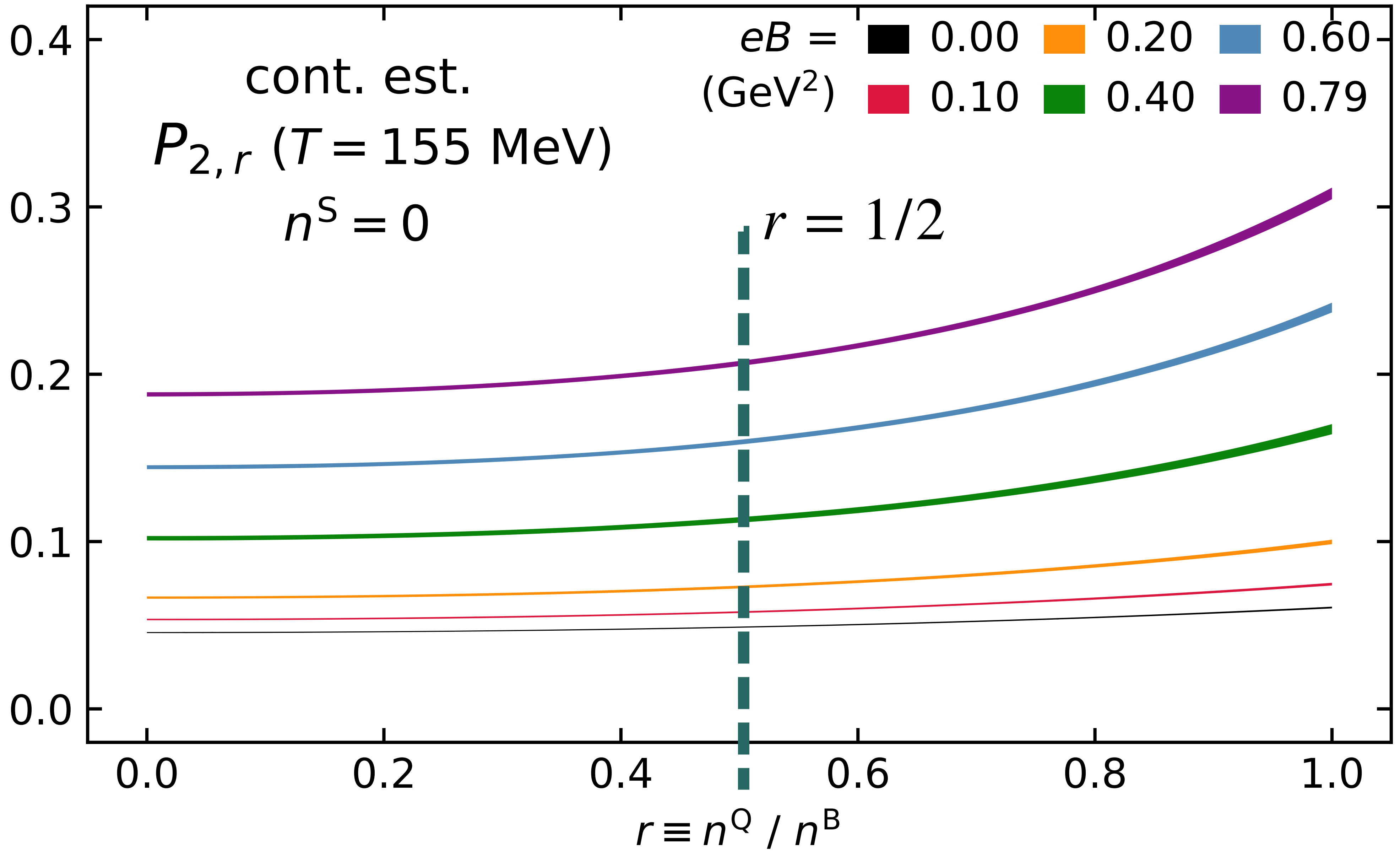
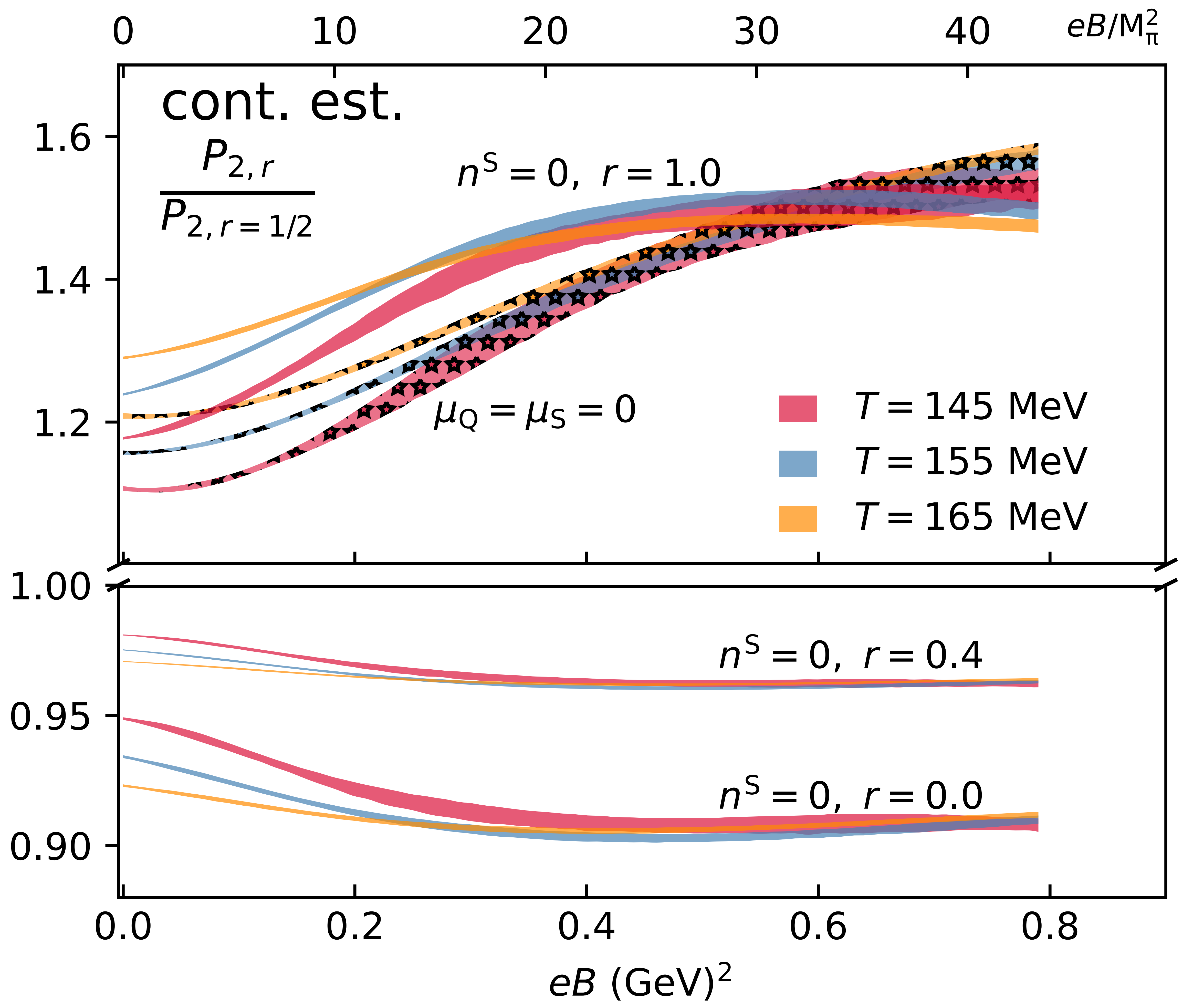


Pressure $\Delta\hat{p}_{\mathrm{LO}} \equiv P_2$: EoS across Systems

- Within strangeness neutral sys: P_2 increases as charged content r increases

- Deviation wrt isospin symmetric case: $r < 0.5$: $\sim 10\,\%$ and $r > 0.5$: $\sim 50\,\%$ at most





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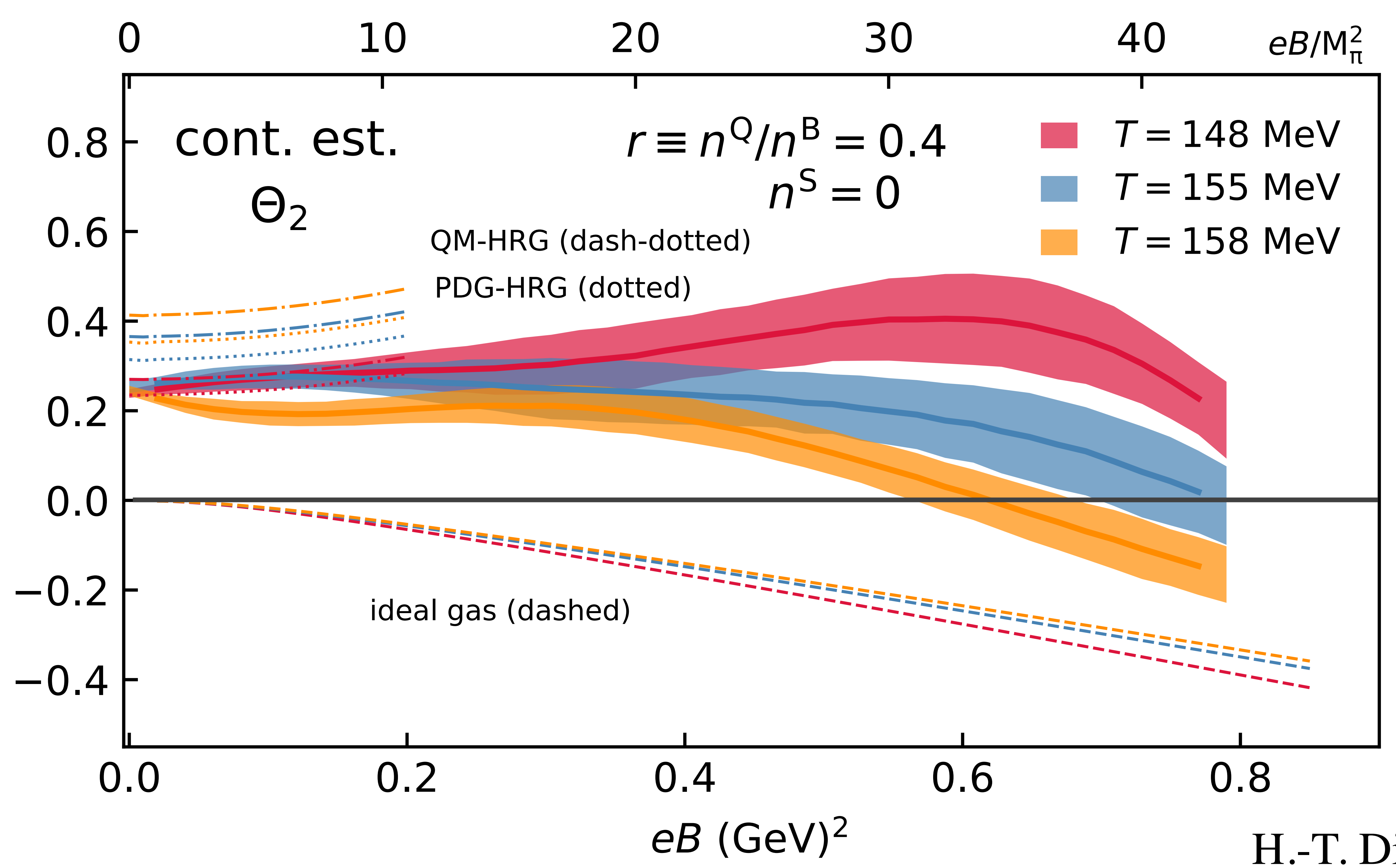
Trace anomaly Θ_2, Energy ϵ_2 & Entropy σ_2 Density

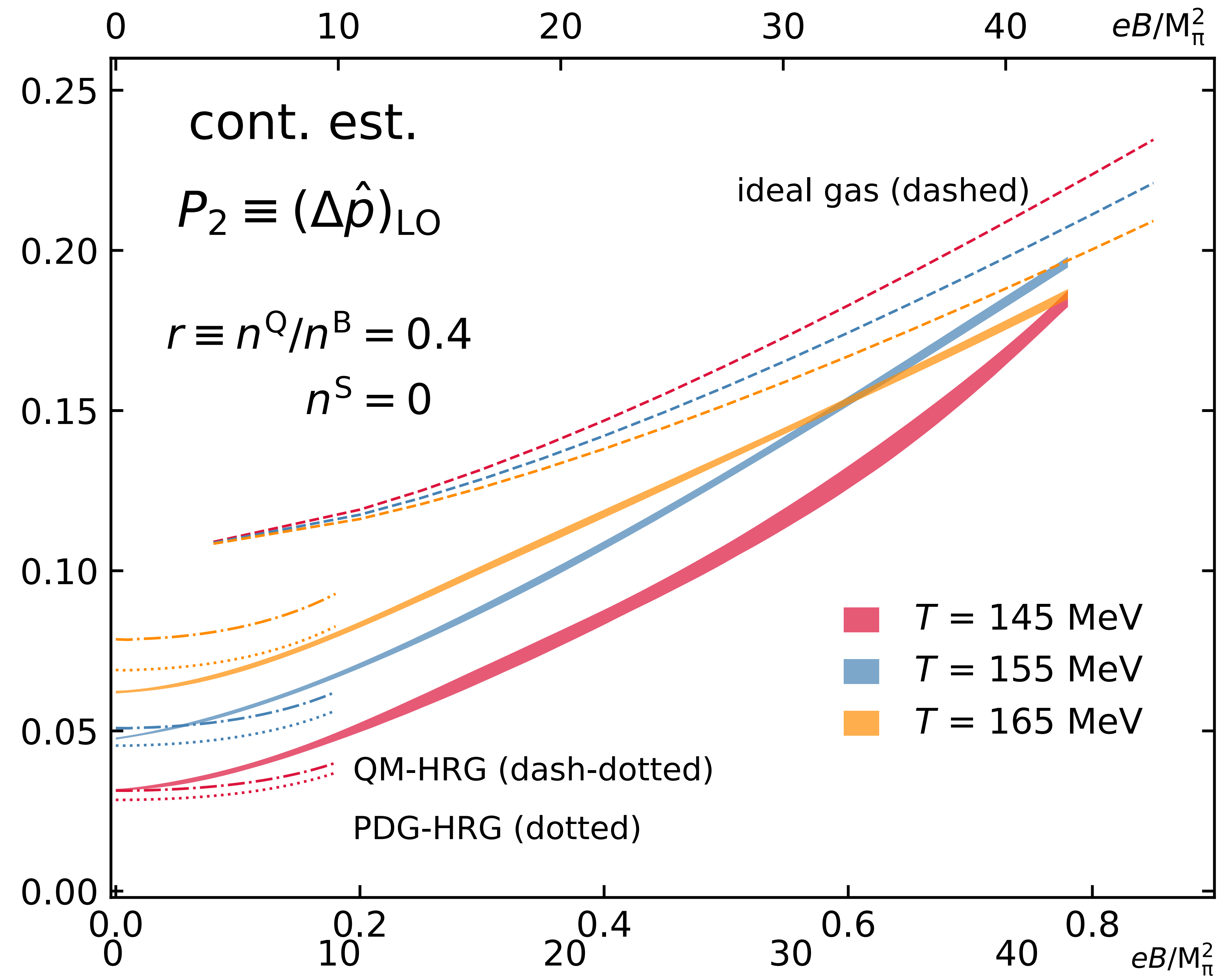
- ☑ T-eB dep. of Θ_2, ϵ_2, σ_2 intricate: P_2, q_1, s_1 and ∂_T

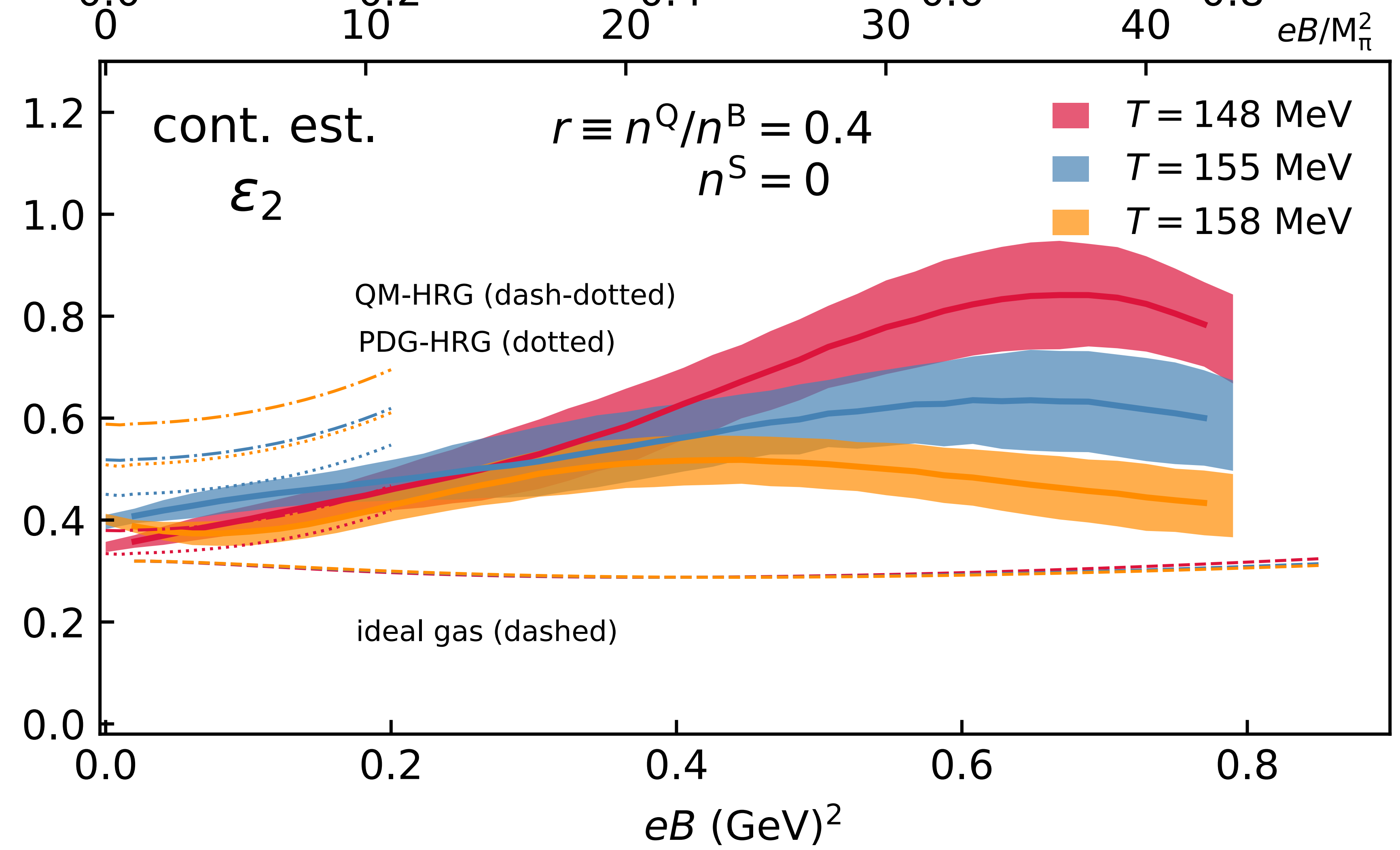
$$\Theta_2(T, eB) = T(\partial_T P_2) - rT(\partial_T q_1)N_1^{\rm B}$$

$$\epsilon_2(T, eB) = 3P_2 + \Theta_2 \qquad \sigma_2(T, eB) = \epsilon_2 + P_2 + T(\partial_T P_2) - (1 + rq_1)N_1^{\rm B}$$

- ☑ P_2 *crossings, peak structure* ⟷ $\Theta_2 < 0 : 3P_2 > \epsilon_2$ *reduced and negative*







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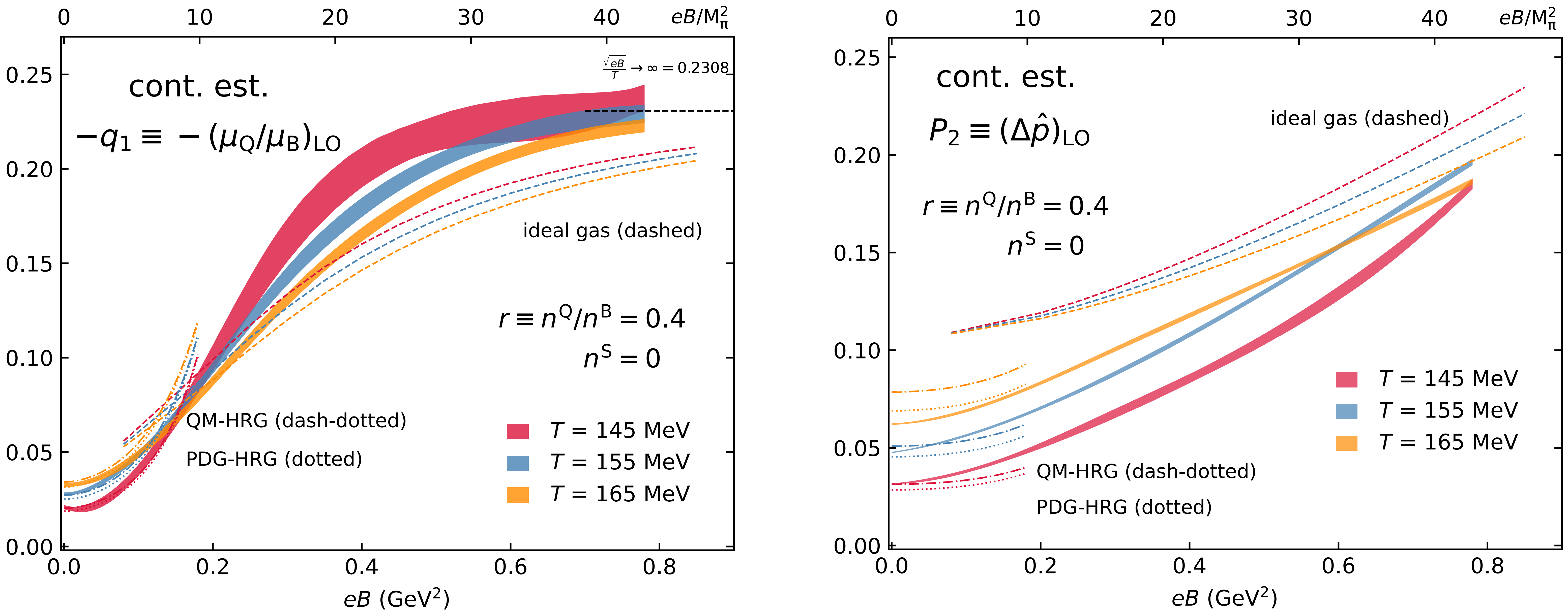
Take Home Message

- Leading-order $(2+1)$-f **QCD EoS** in strong magnetic fields using fluctuations of conserved charges
- $q_1,\ s_1$: HRG breaks down and approach saturation to magnetized ideal gas
- P_2 : Crossing among fixed T bands → Non-monotonic/peak T-growth → T_{pc}-lowering



Thank You for your time & attention!

Some Backups!

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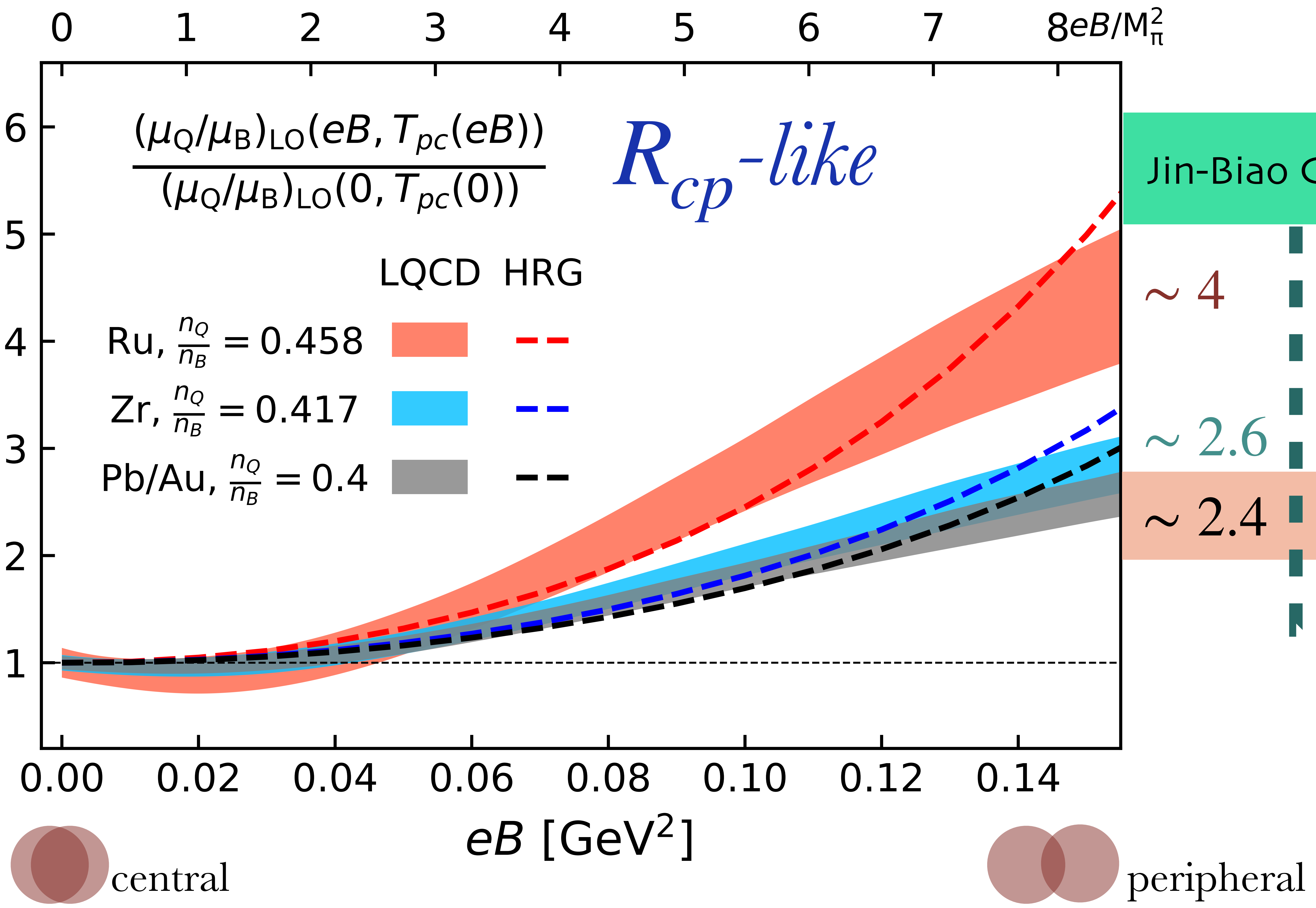
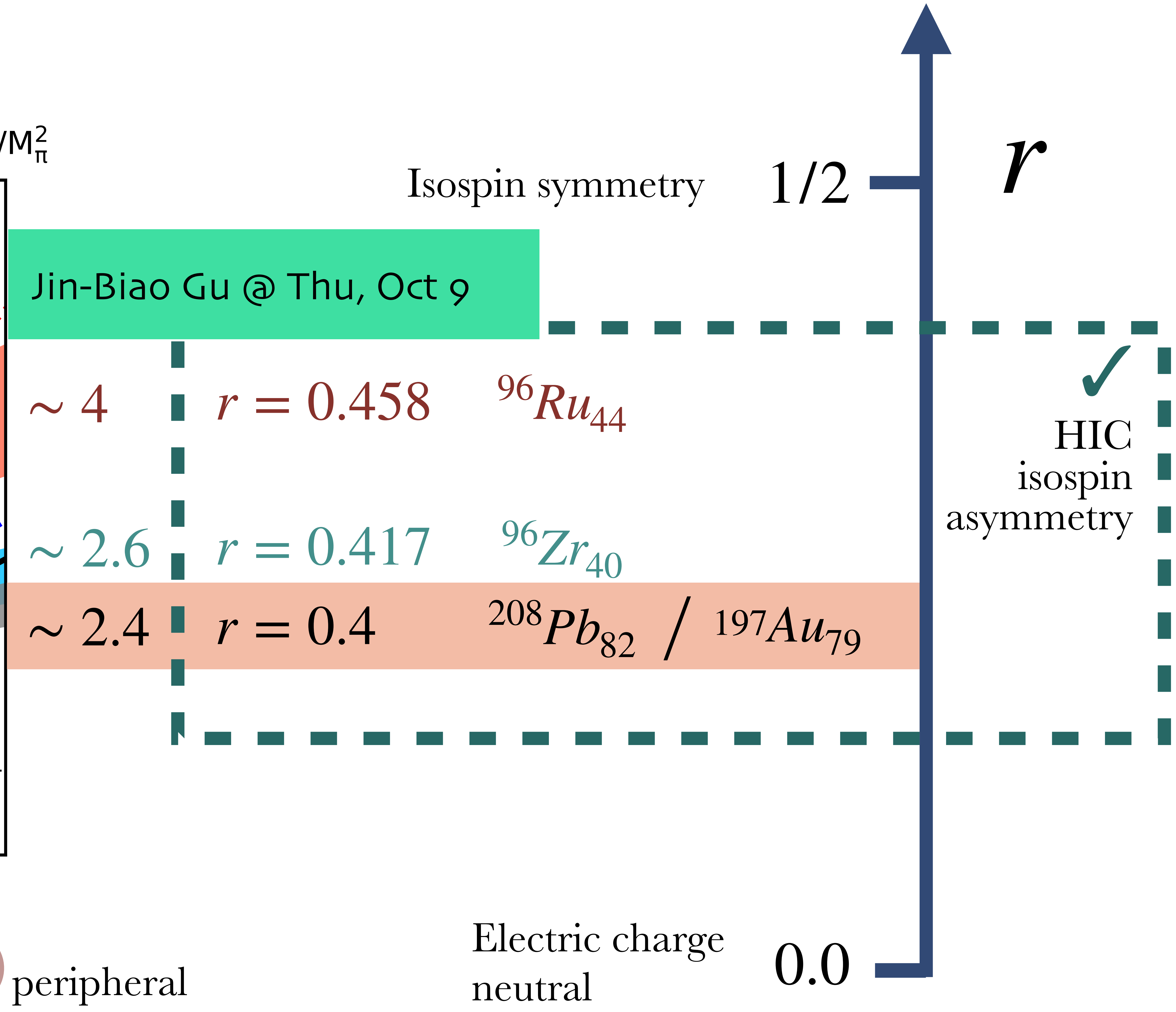
$(\mu_Q/\mu_B)_{LO} \equiv q_1$: QCD Magnetometer



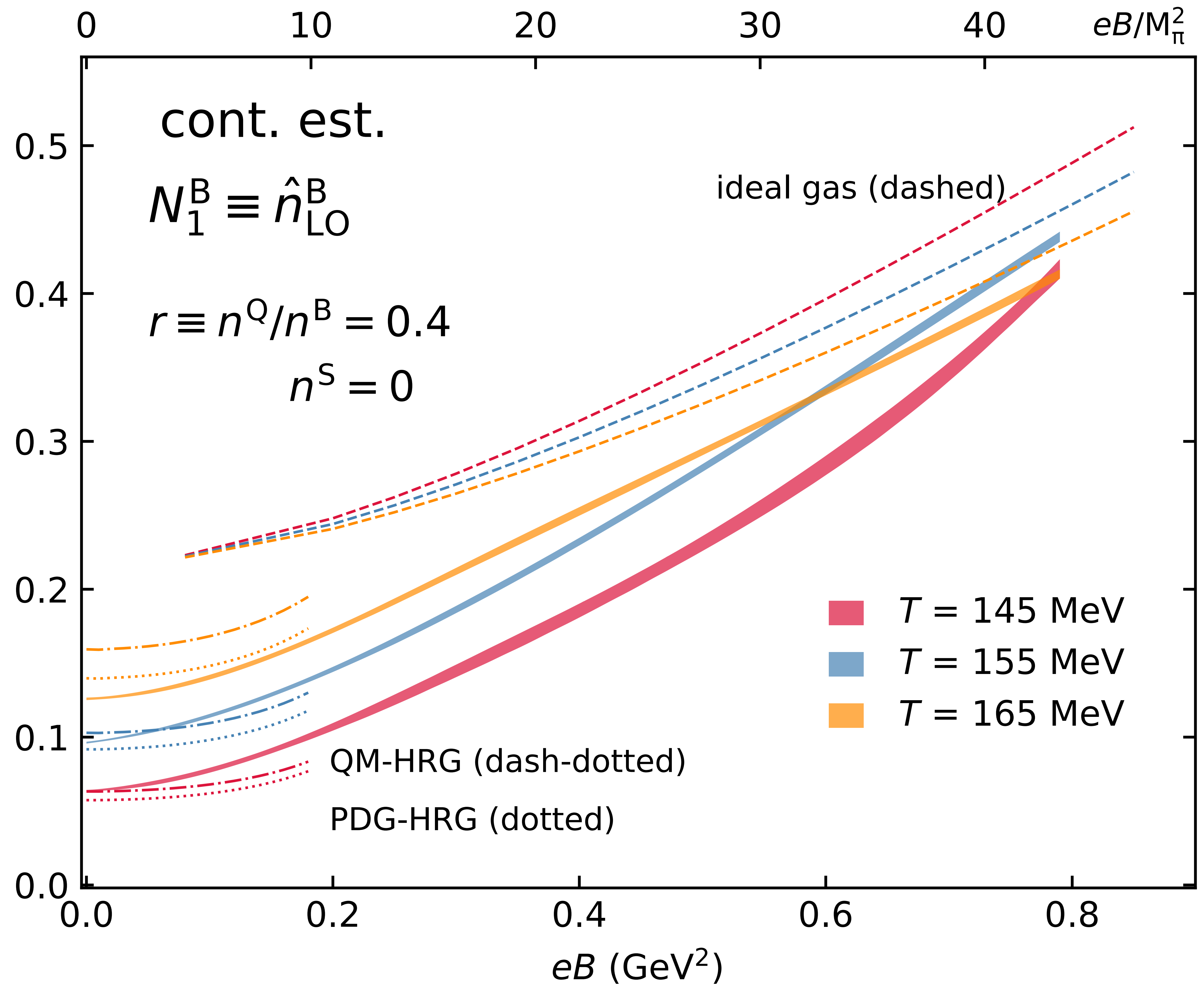


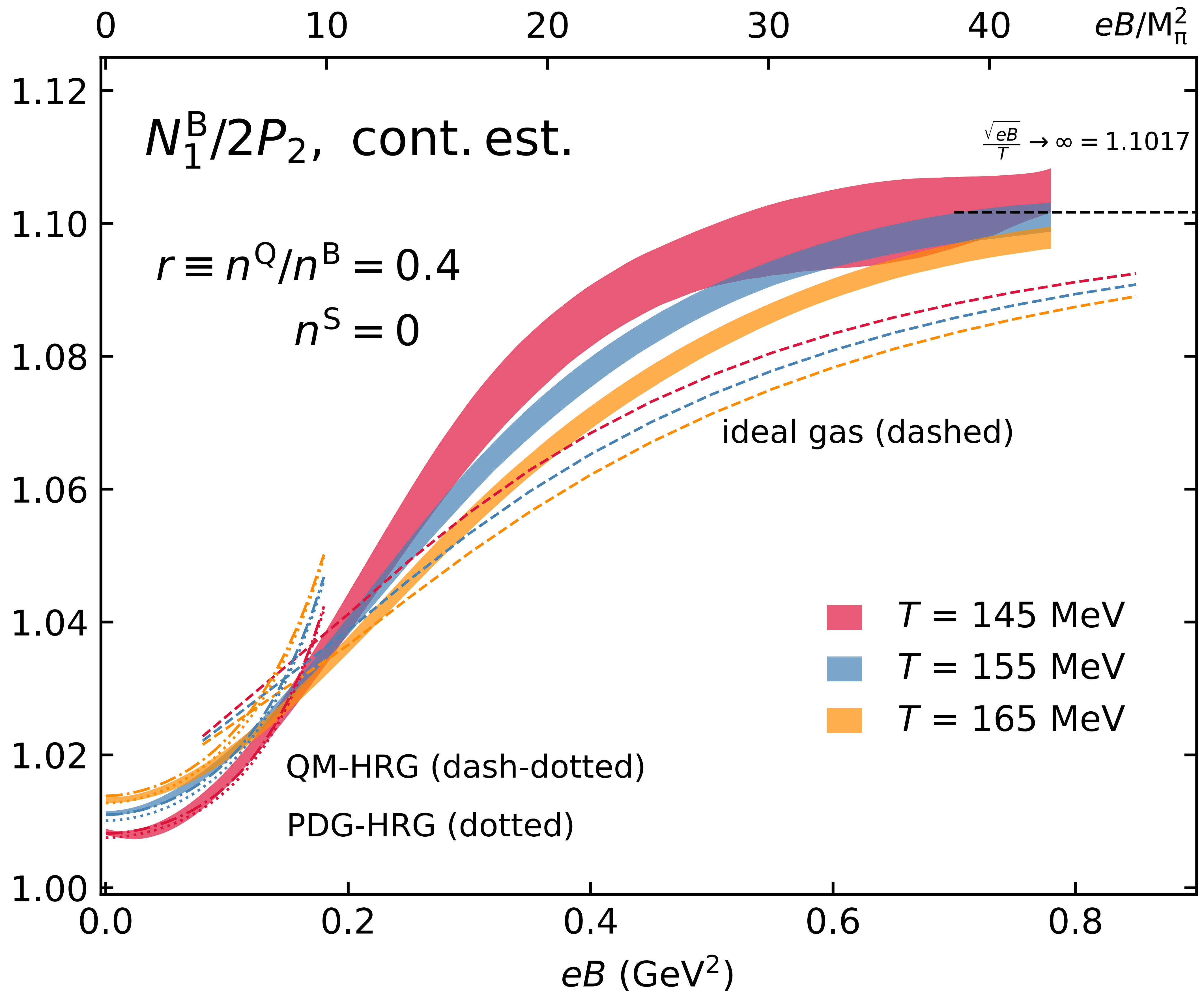
H.-T. Ding, J.-B. Gu, A. K, S.-T. Li, J.-H. Liu,
PRL 132 (2024) 201903

$\hat{n}^{\mathrm{B}}_{\mathrm{LO}} \equiv N^{\mathrm{B}}_1$: Baryon Density

$$N_1^{\mathrm{B}} = \chi_2^{\mathrm{B}} + q_1\chi_{11}^{\mathrm{BQ}} + s_1\chi_{11}^{\mathrm{BS}} \qquad \frac{N_1^B}{2P_2} = \frac{1}{1+rq_1}$$

- ☑ Similar T-eB dependence to pressure; magnitude $\sim 2P_2$
- ☑ $N_1^B/2P_2$ deviation from unity: isospin symmetry breaking



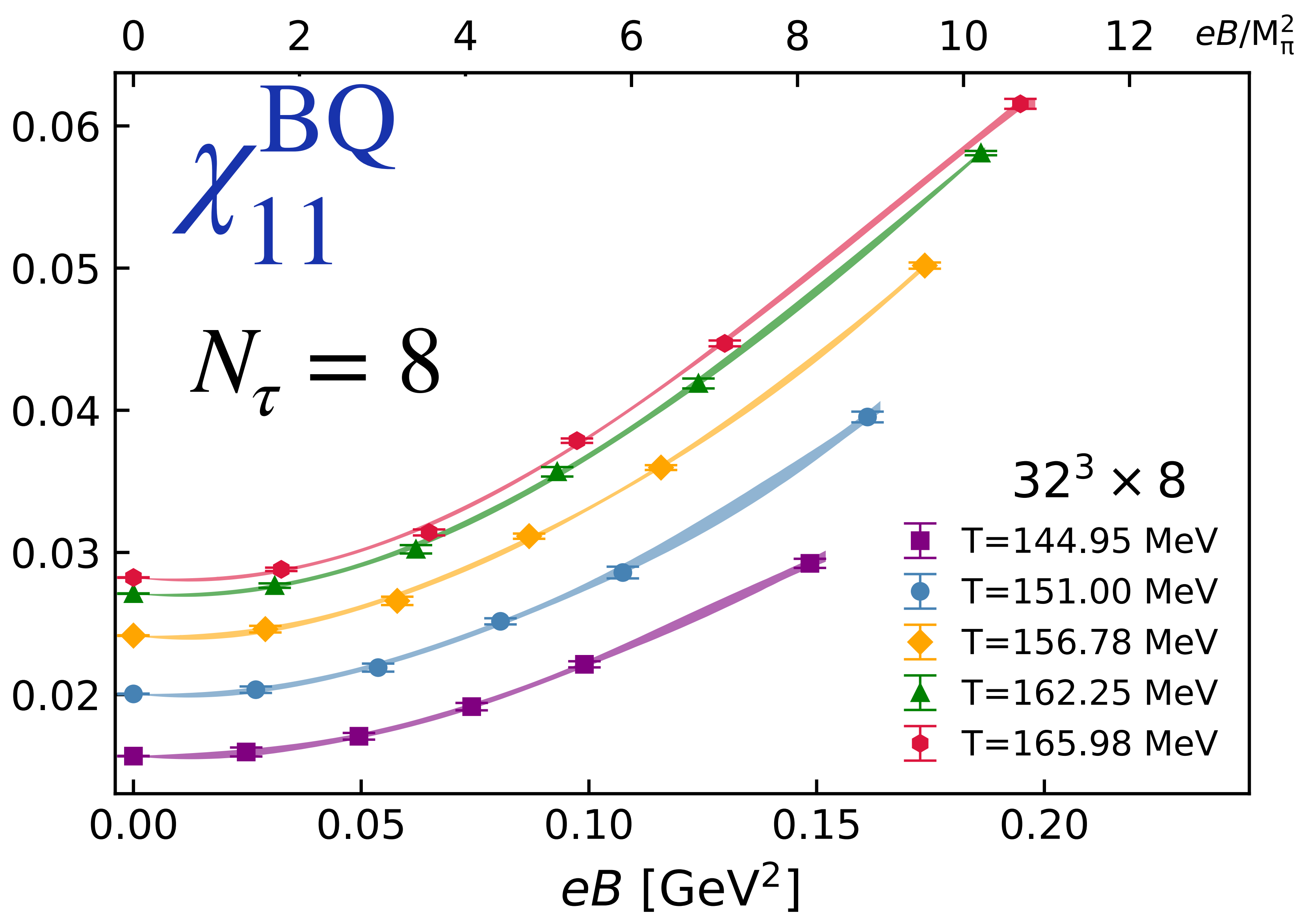


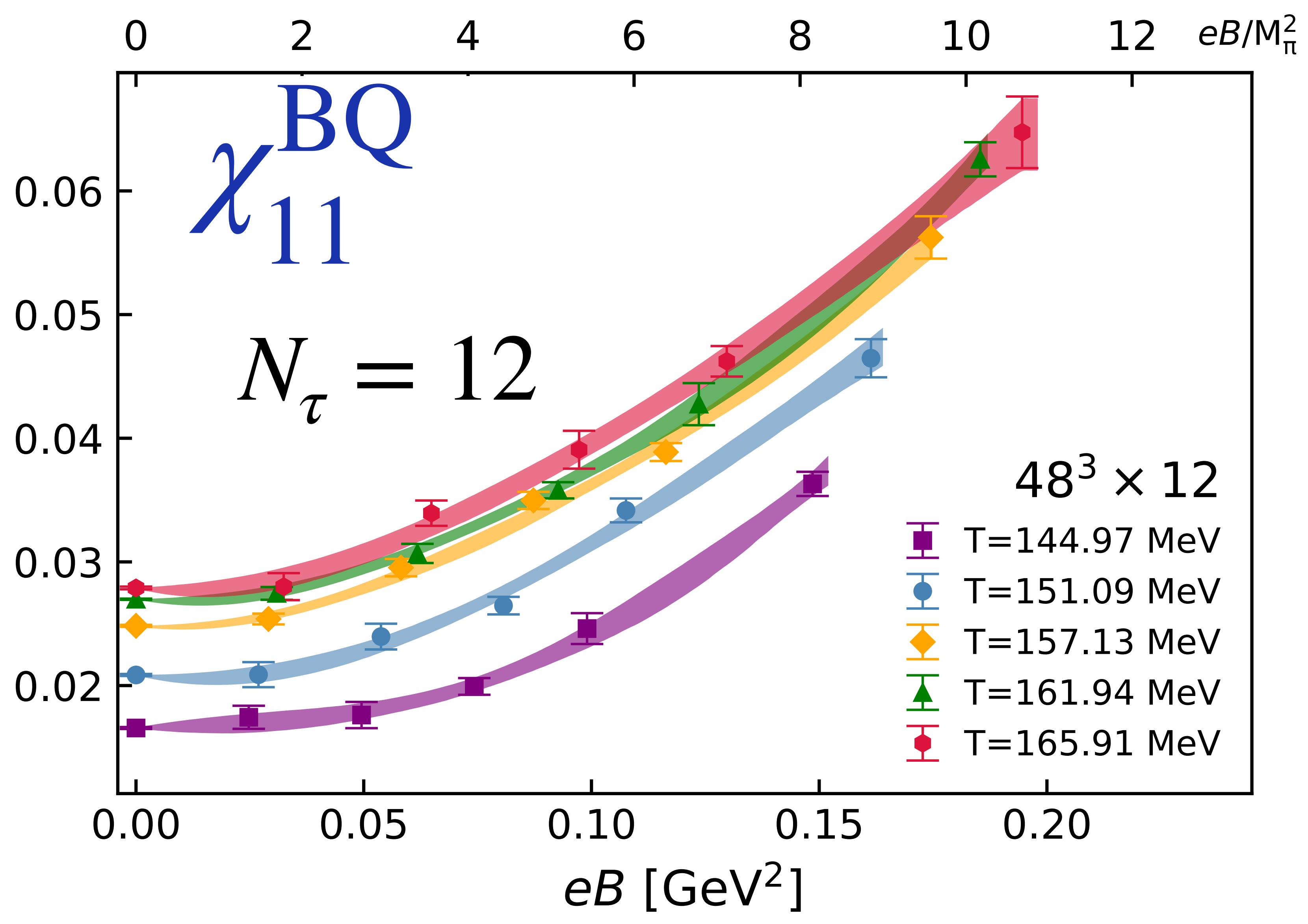
H.-T. Ding, J.-B. Gu, A. Kumar, S.-T. Li, *arXiv:2508.07532 [hep-lat]*

Lattice Data and Setup at $N_\tau = 8, 12$

$(N_\sigma / N_\tau = 4)$

Nuclear Science Computing Center at CCNU





H.-T. Ding, J.-B. Gu, **AK**, S.-T. Li, J.-H. Liu, **PRL 132 (2024) 201903**

SETUP:

- HISQ & tree action with physical pion mass
- Temperature : focused around QCD transition $T \equiv [145 - 166)$ MeV
- Magnetic field : Quantized: $eB = 6\pi N_b \, a^{-2} N_\sigma^{-2}$

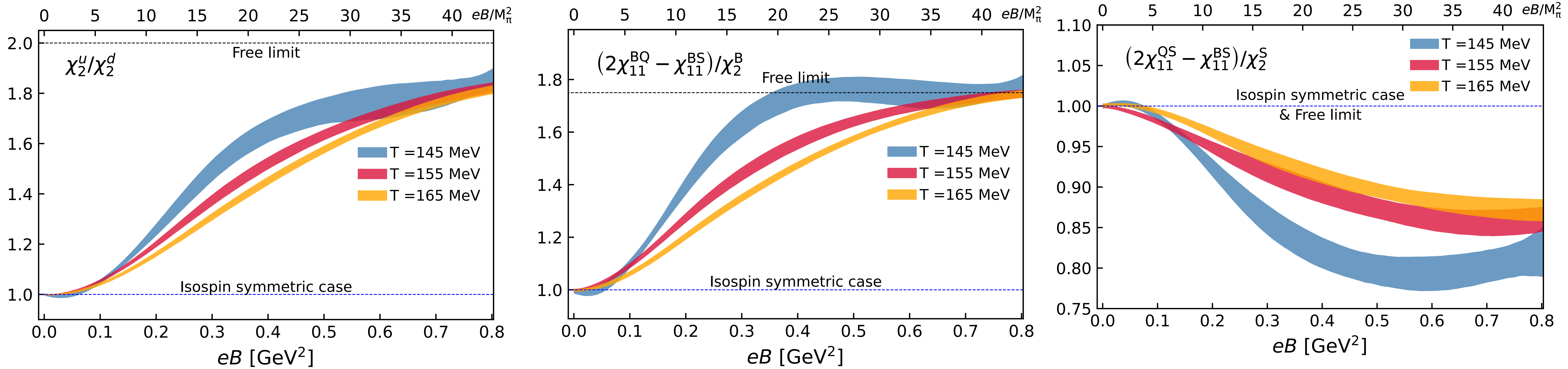
  $N_b = [1 - 6] \;\rightarrow\; eB \lesssim 0.15 \text{ GeV}^2 \sim 8M_\pi^2$

M. D'Elia, S. Mukherjee, F. Sanfilippo, **PRD** 82 (2010), 051501

2nd order Fluctuations Strong-eB at $T = 145$ MeV

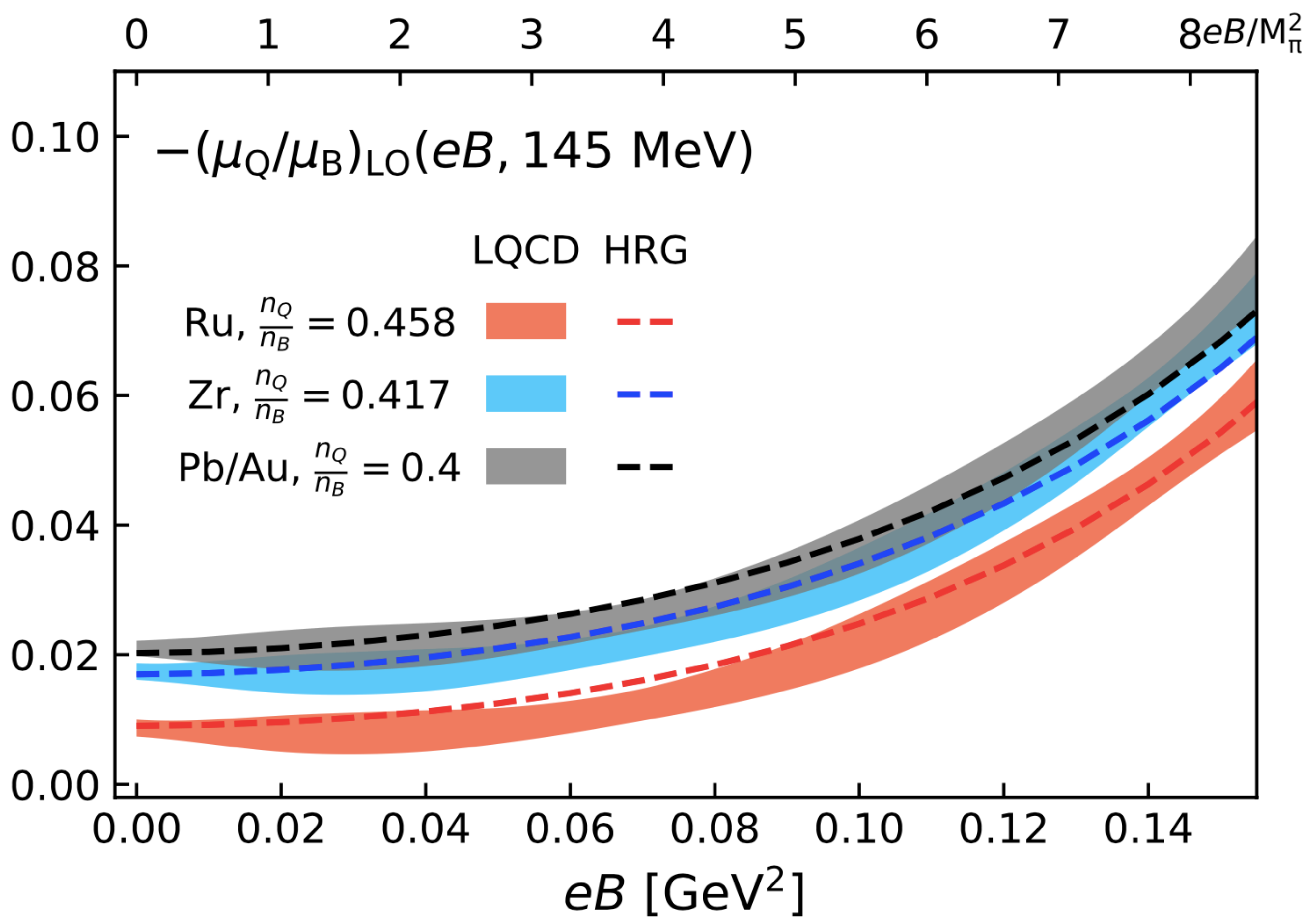
H.-T. Ding, J.-B. Gu, **AK**, S.-T. Li, **PRD** 111 (2025) 11, 114522

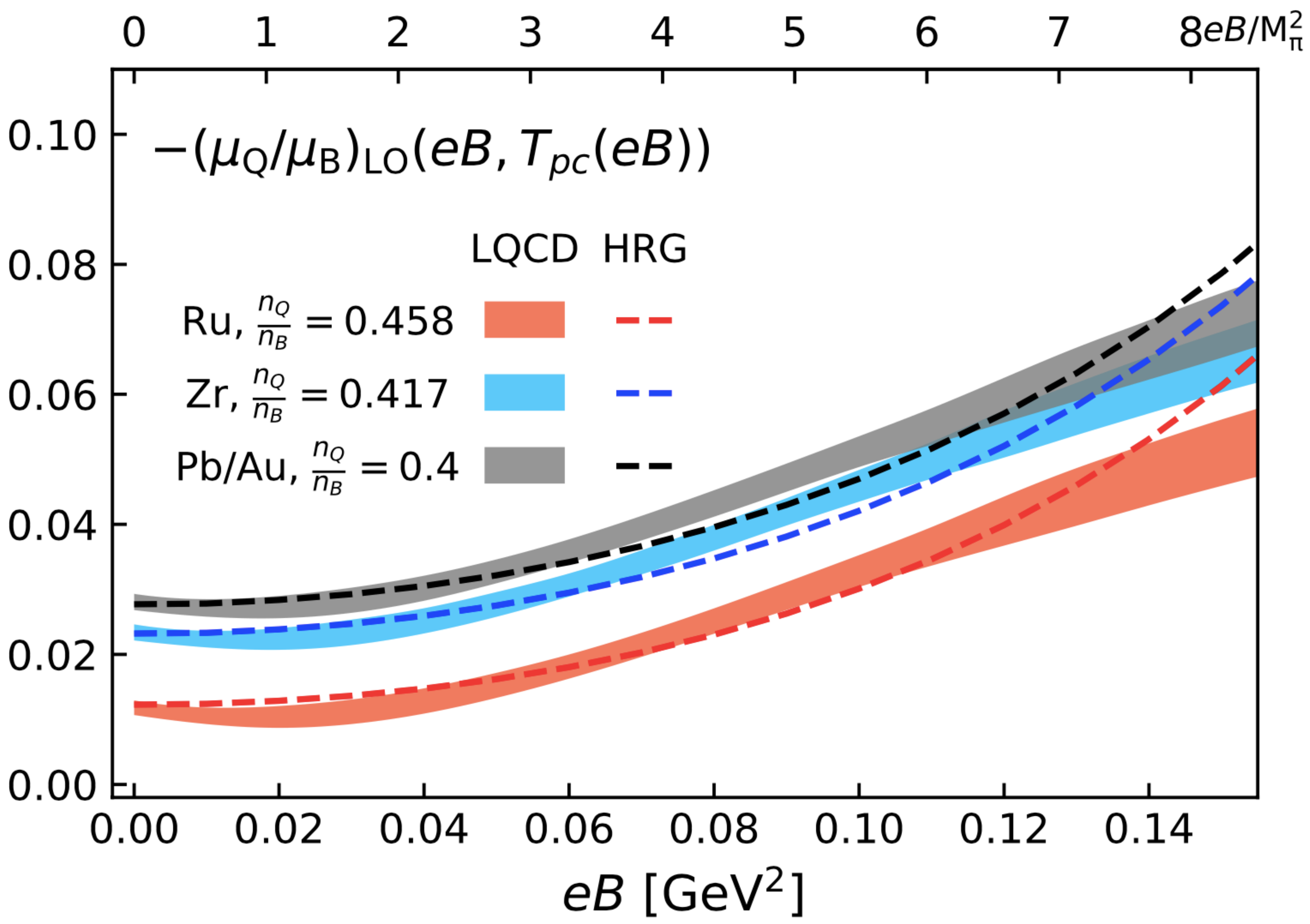
Isospin symmetry breaking in strong fields



H.-T. Ding, J.-B. Gu, **AK**, S.-T. Li, **PRD** 111 (2025) 11, 114522

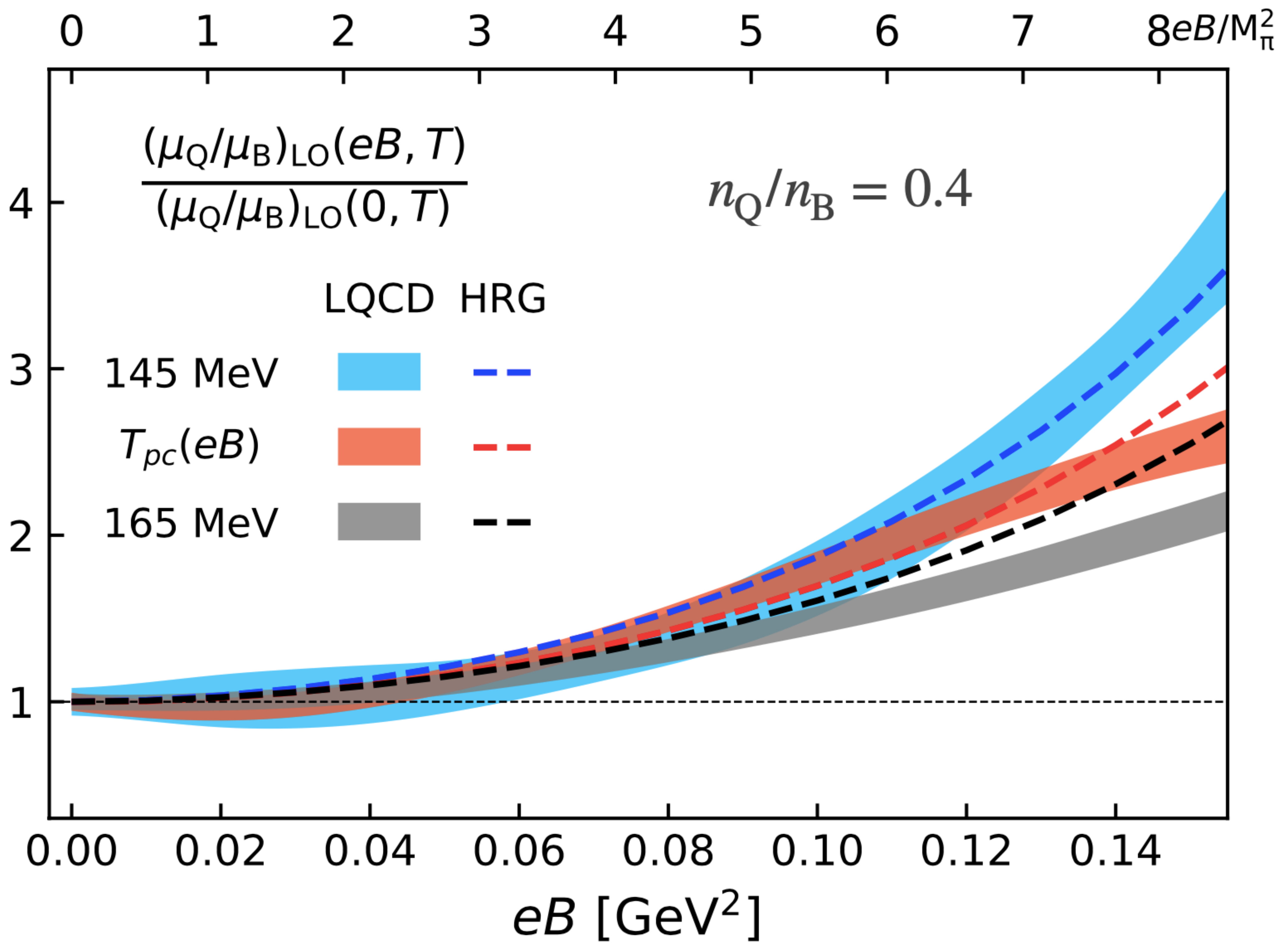
$(\mu_Q/\mu_B)_{LO} \equiv q_1$: Collision Systems

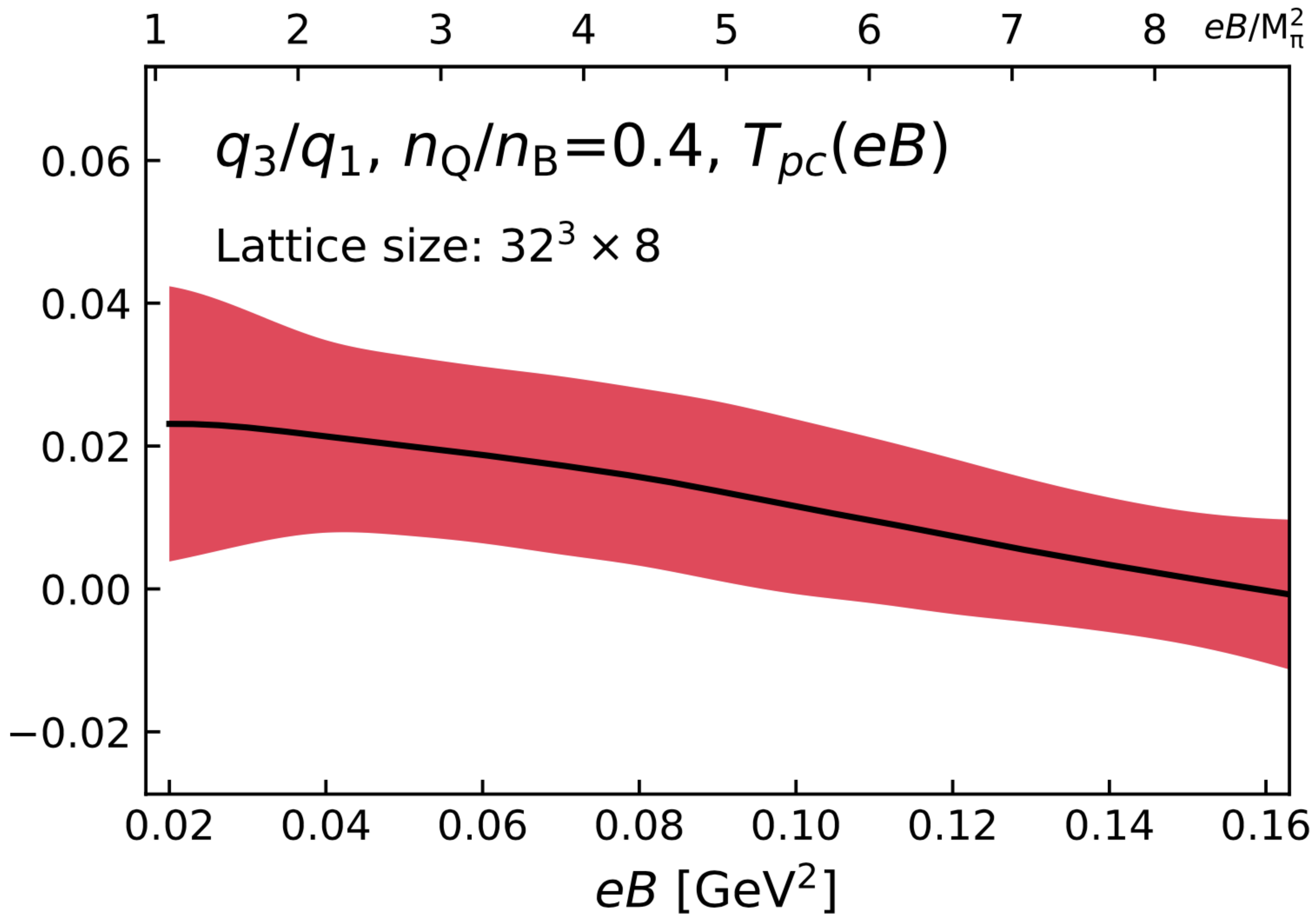




H.-T. Ding, J.-B. Gu, **AK**, S.-T. Li, J.-H. Liu, **PRL 132 (2024) 201903**

$(\mu_Q/\mu_B)_{LO} \equiv q_1$: Collision Systems



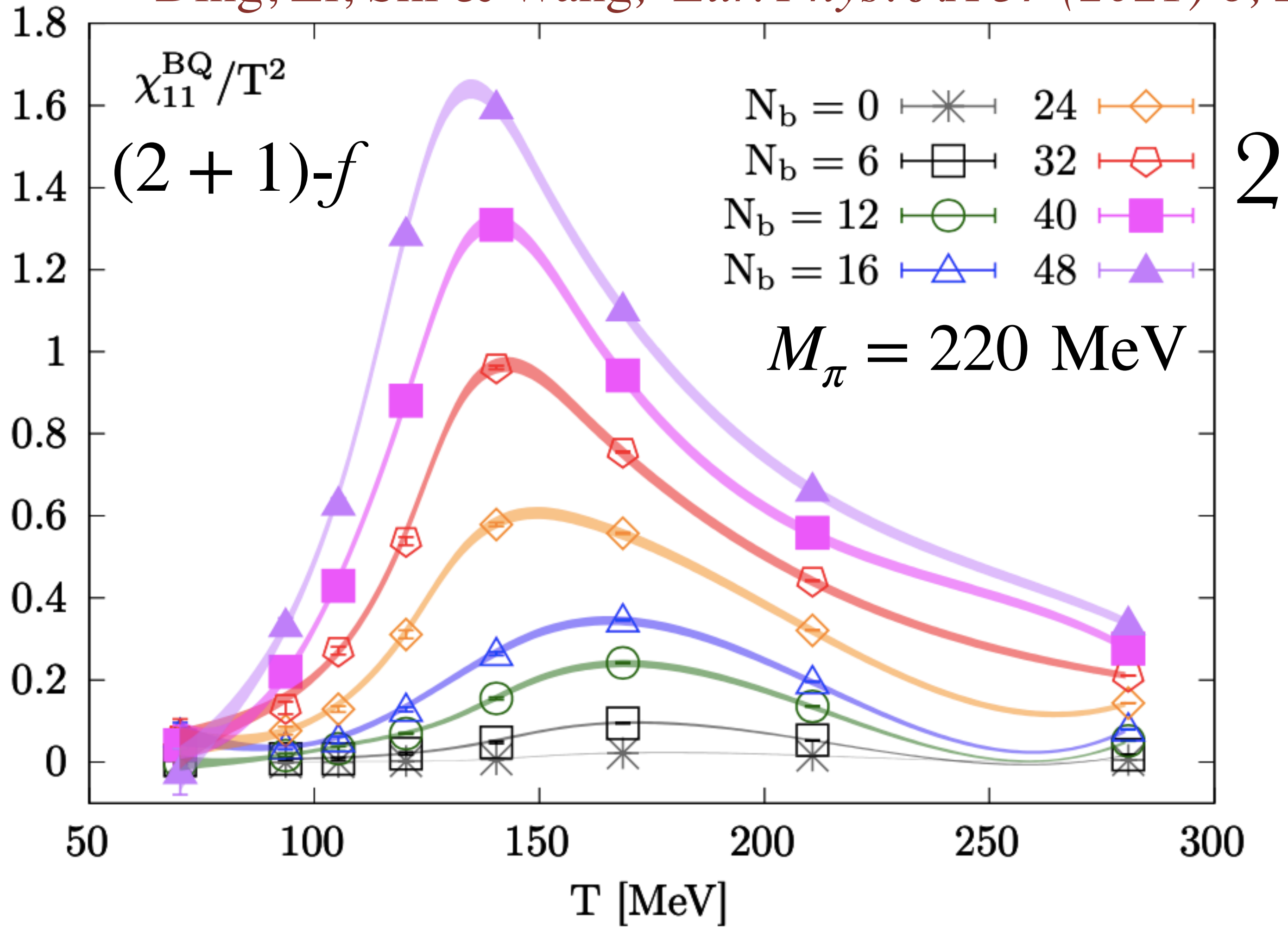


H.-T. Ding, J.-B. Gu, **AK**, S.-T. Li, J.-H. Liu, **PRL 132 (2024) 201903**

Recent Lattice Works: Conserved Charges in Magnetic fields

χ_{ijk}^{BQS}

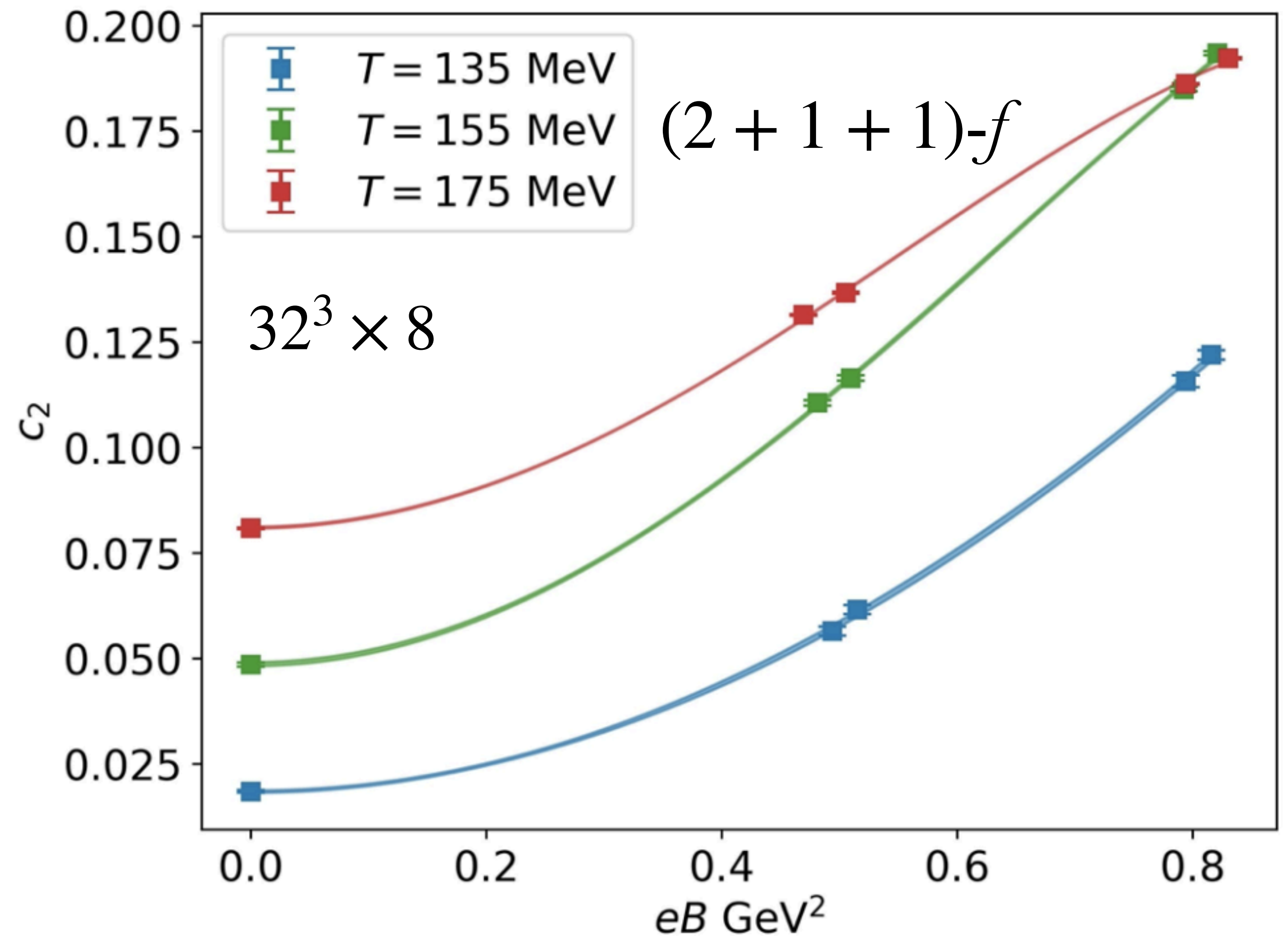
Ding, Li, Shi & Wang, *Eur. Phys. J.A* ***57*** *(2021) 6, 202*



2021

EoS: Pressure

Borsanyi et al., *PoS* ***LATTICE2023*** *(2024) 164*

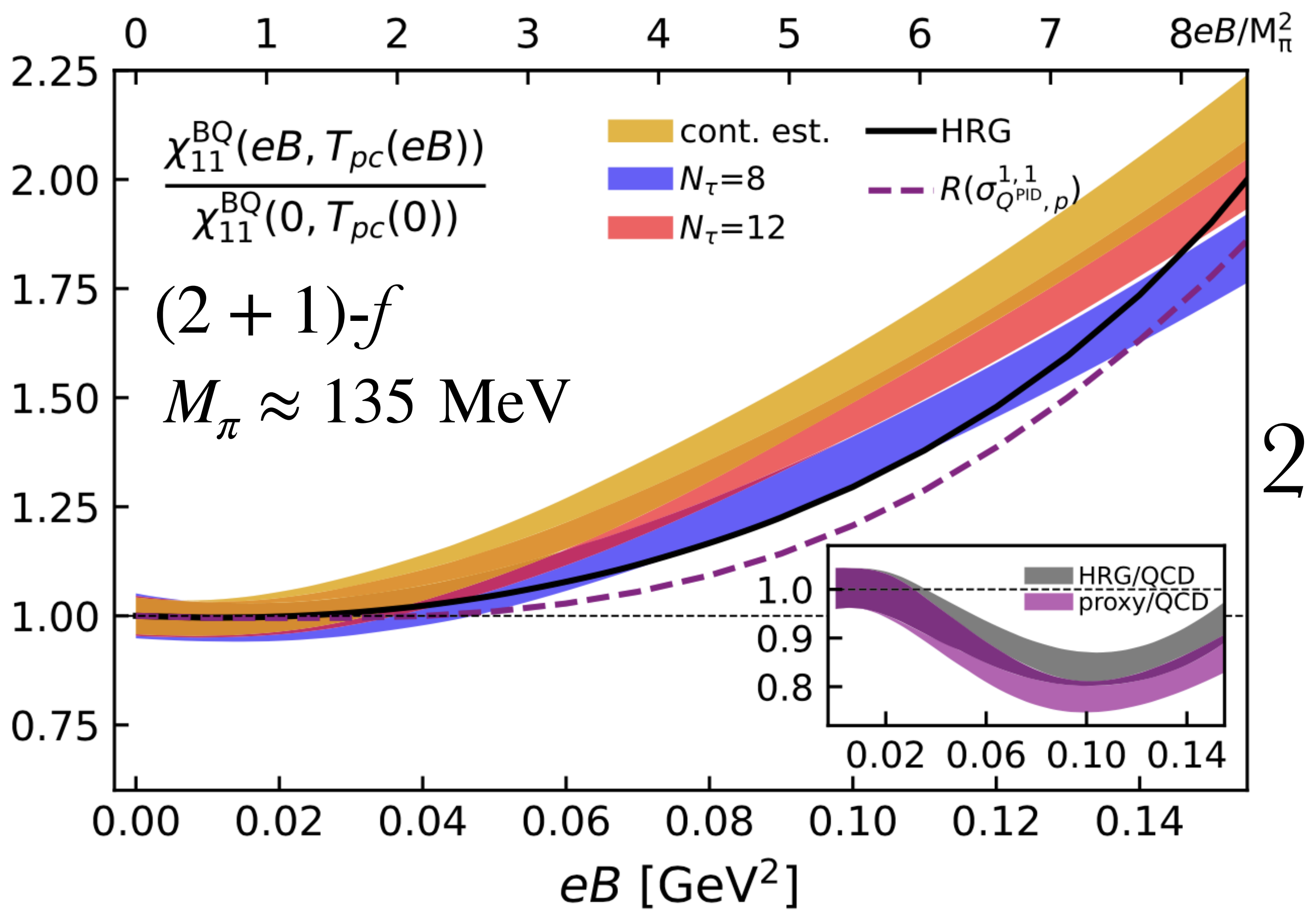


2023

★ Recent review article:

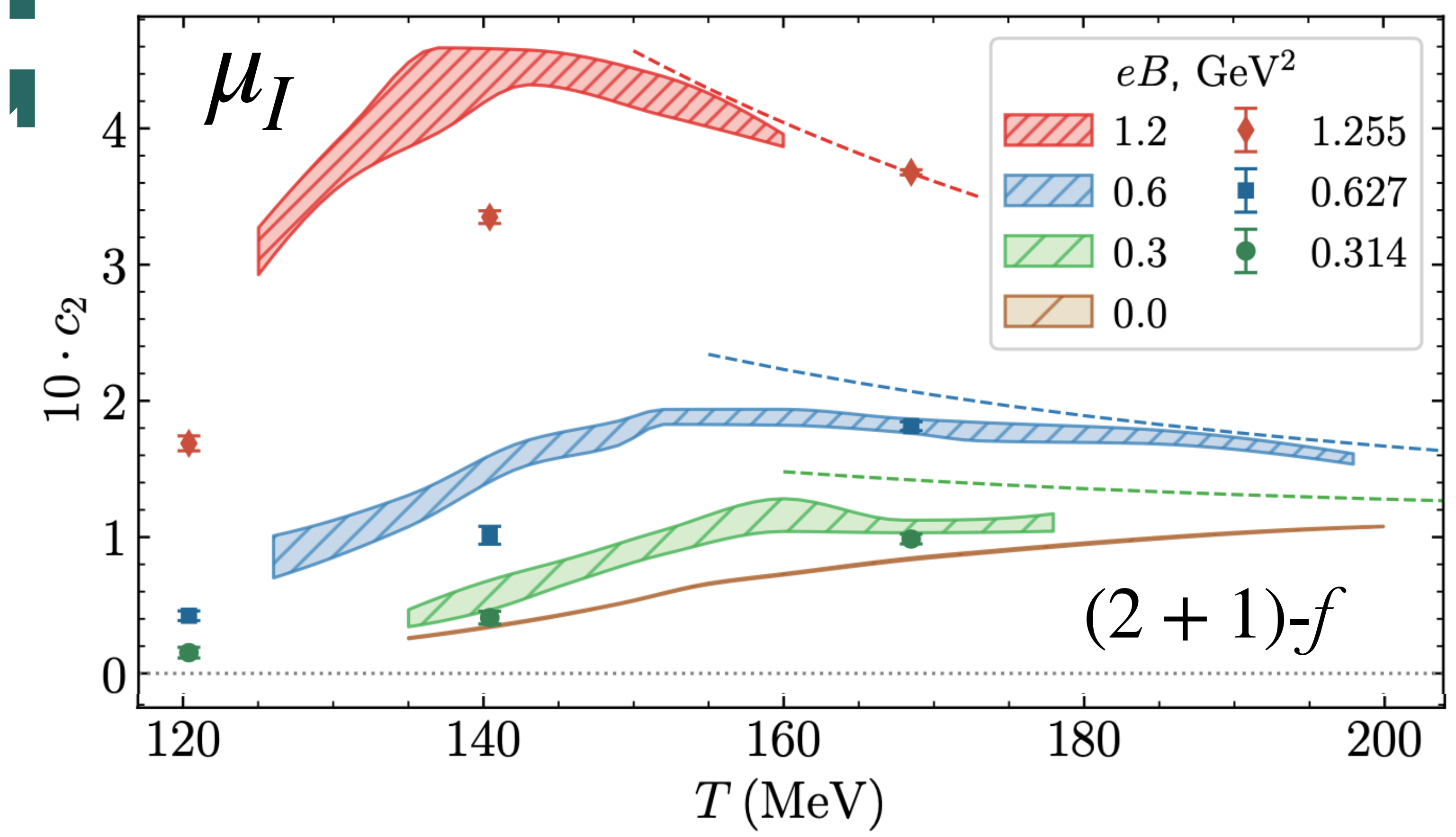
"QCD with background electromagnetic fields on the lattice: a review"

Endrodi, arXiv:2406.19780



2023

Ding, Gu, Kumar, Li & Liu, *Phys. Rev. Lett.* ***132****, 201903 (2024)*

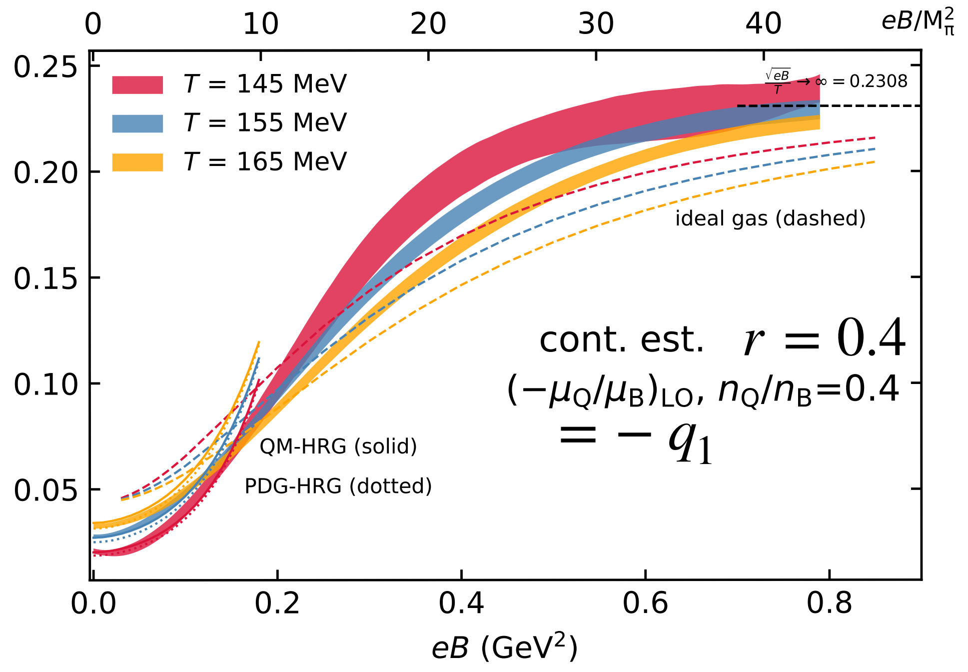


2024

Astrakhantsev et al., *Phys.Rev.D* ***109*** *(2024) 9, 094511*

$\mu_{\mathrm{Q}}/\mu_{\mathrm{B}}$ IN PRESENCE OF eB

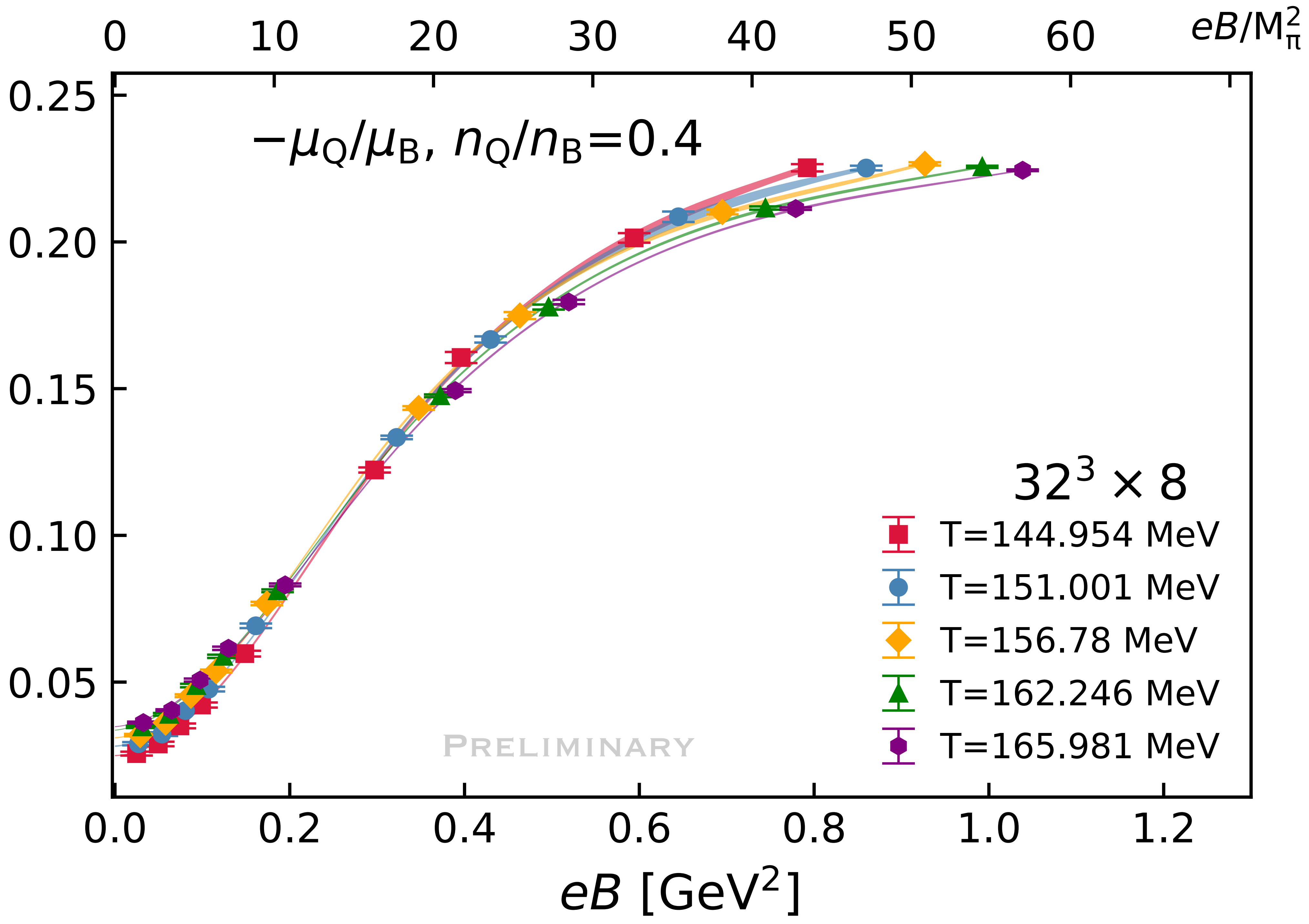
$$q_1 = \frac{r\left(\chi_2^{\mathrm{B}}\chi_2^{\mathrm{S}} - \chi_{11}^{\mathrm{BS}}\chi_{11}^{\mathrm{BS}}\right) - \left(\chi_{11}^{\mathrm{BQ}}\chi_2^{\mathrm{S}} - \chi_{11}^{\mathrm{BS}}\chi_{11}^{\mathrm{QS}}\right)}{\left(\chi_2^{\mathrm{Q}}\chi_2^{\mathrm{S}} - \chi_{11}^{\mathrm{QS}}\chi_{11}^{\mathrm{QS}}\right) - r\left(\chi_{11}^{\mathrm{BQ}}\chi_2^{\mathrm{S}} - \chi_{11}^{\mathrm{BS}}\chi_{11}^{\mathrm{QS}}\right)}$$

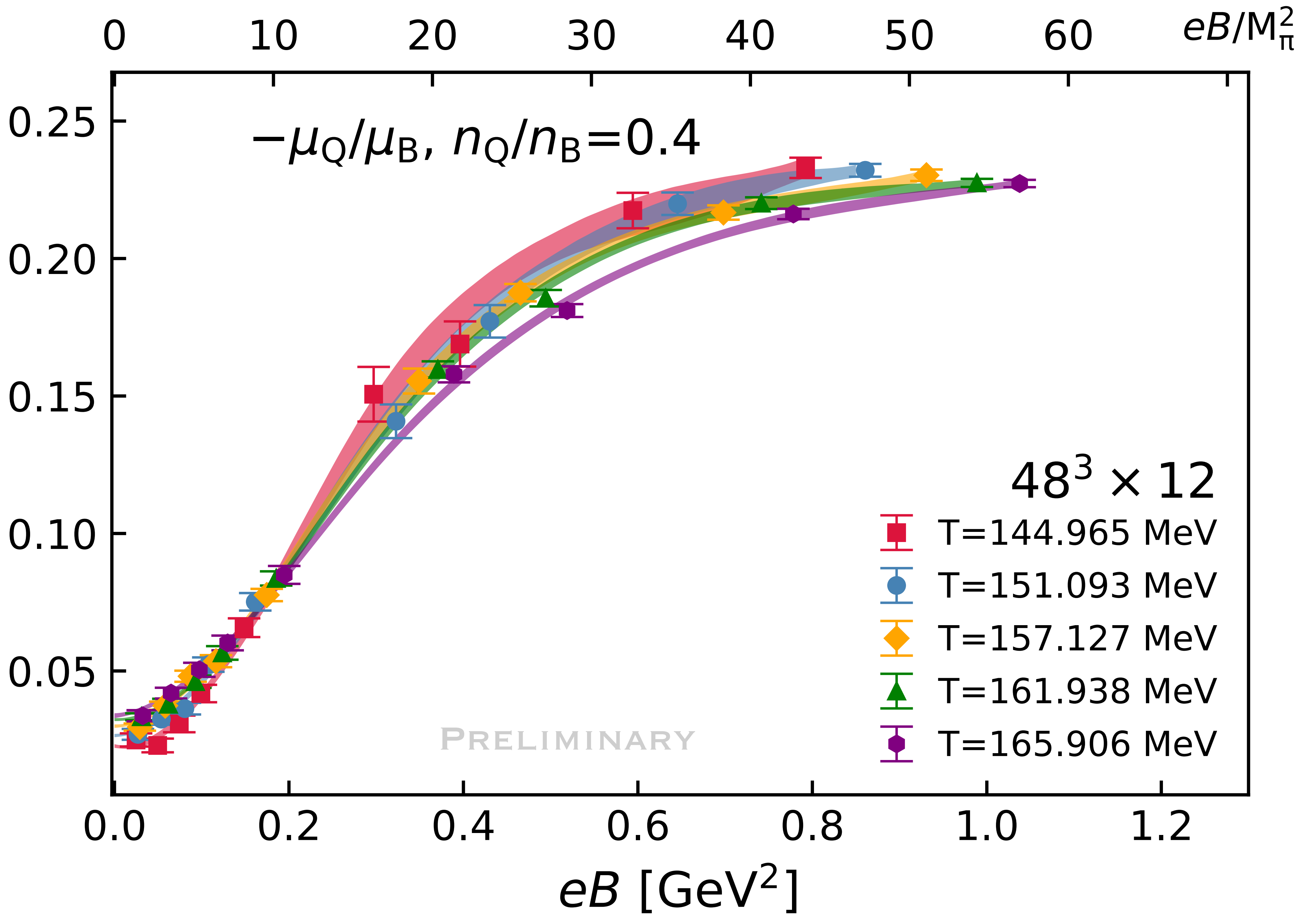


$T \in [145 - 166)$ MeV

$eB \in [0.0 - 0.8)$ GeV^2

A. Lattice data + spline interpolation



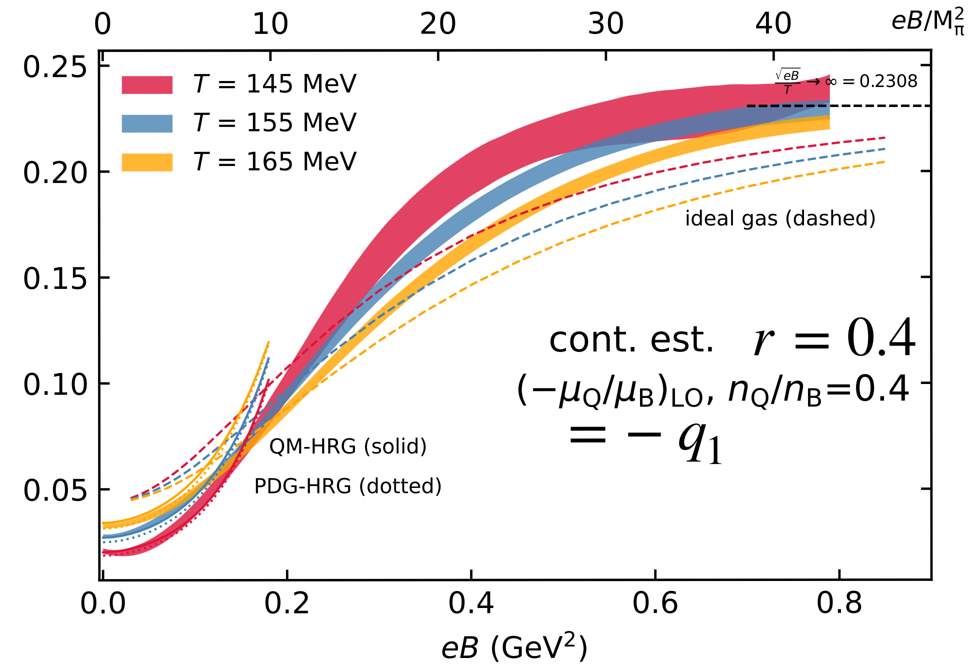


μ_Q/μ_B IN PRESENCE OF eB

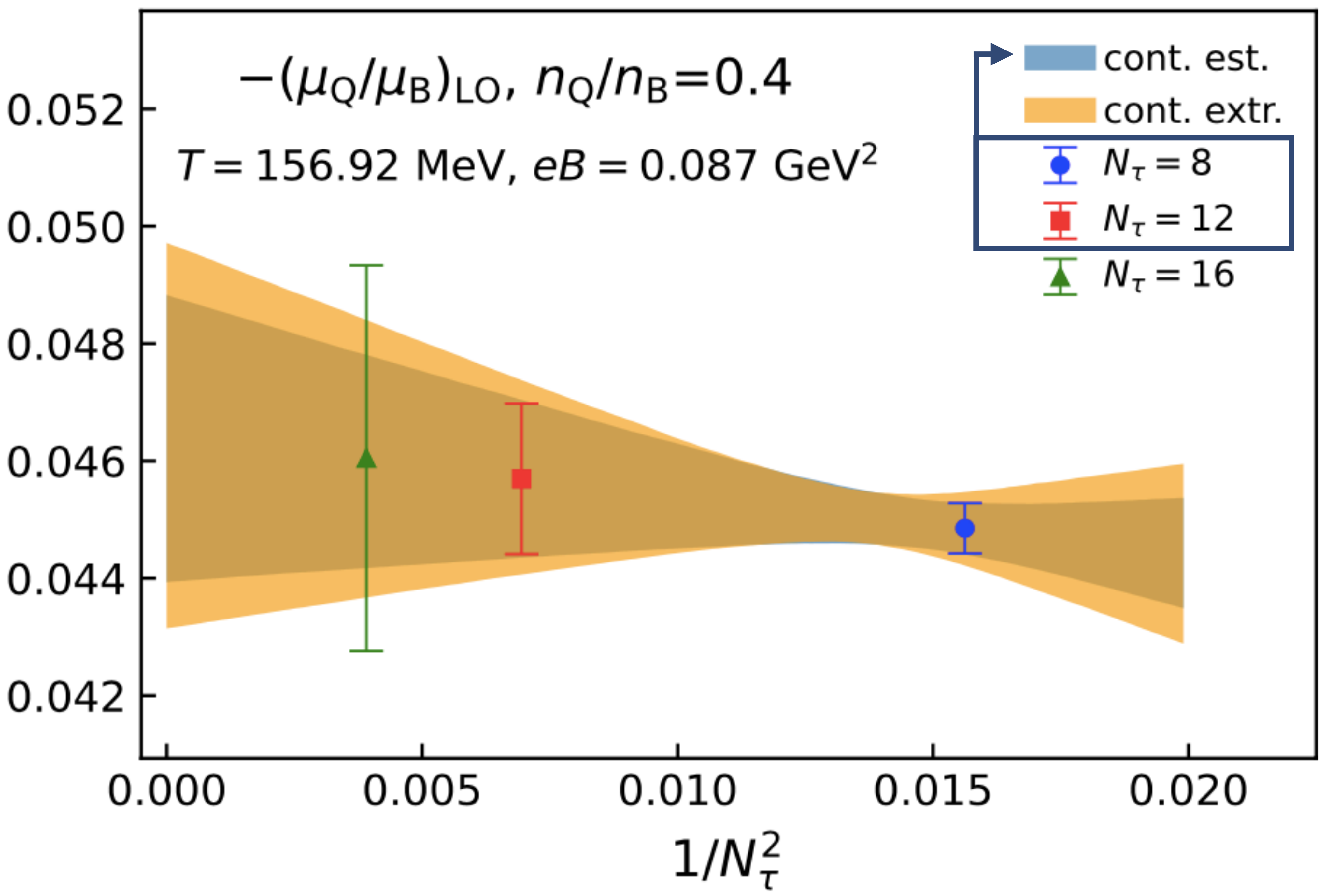
$$q_1 = \frac{r\left(\chi_2^{B}\chi_2^{S} - \chi_{11}^{BS}\chi_{11}^{BS}\right) - \left(\chi_{11}^{BQ}\chi_2^{S} - \chi_{11}^{BS}\chi_{11}^{QS}\right)}{\left(\chi_2^{Q}\chi_2^{S} - \chi_{11}^{QS}\chi_{11}^{QS}\right) - r\left(\chi_{11}^{BQ}\chi_2^{S} - \chi_{11}^{BS}\chi_{11}^{QS}\right)}$$

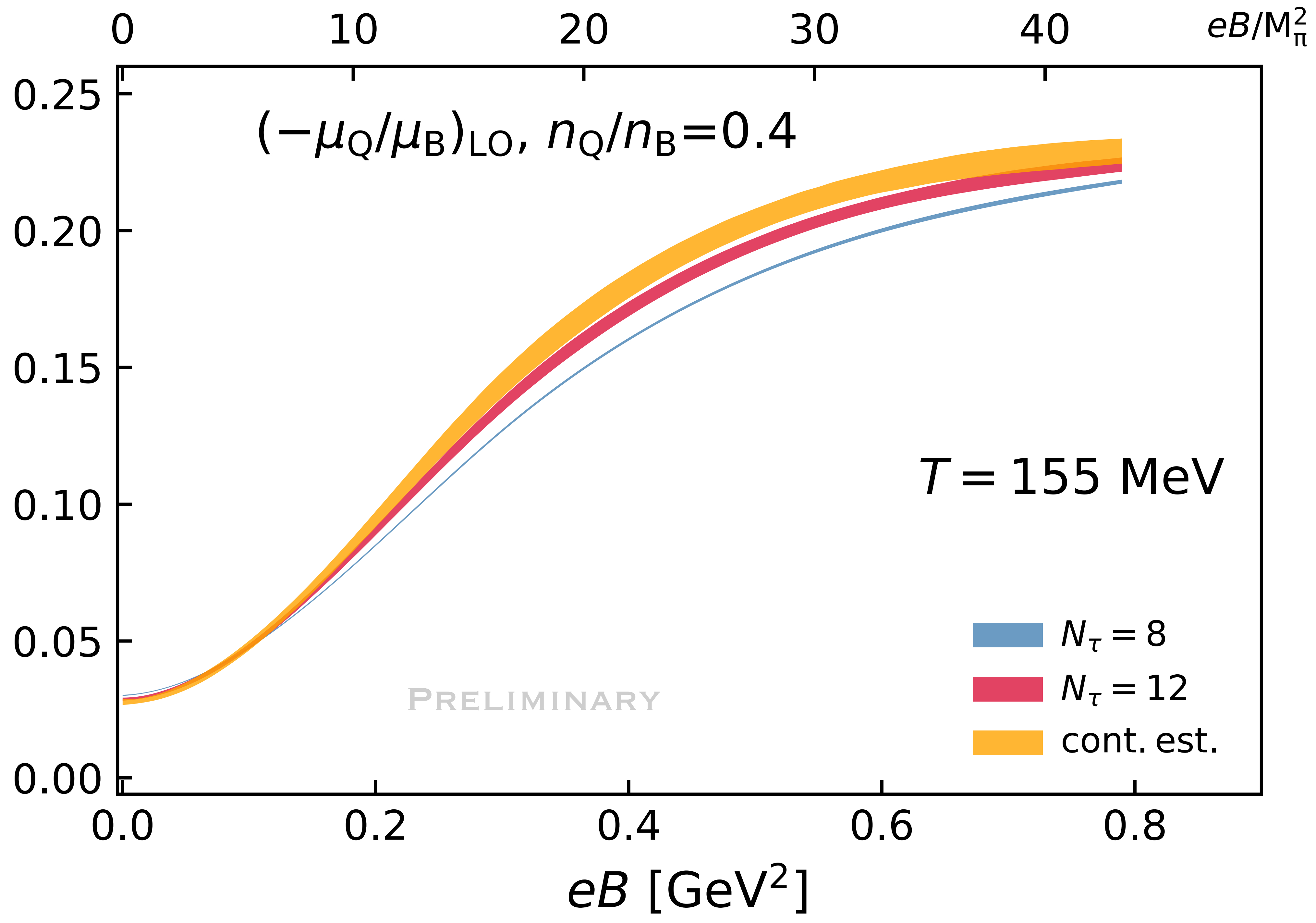
$T \in [145 - 166)$ MeV

$eB \in [0.0 - 0.8)$ GeV^2

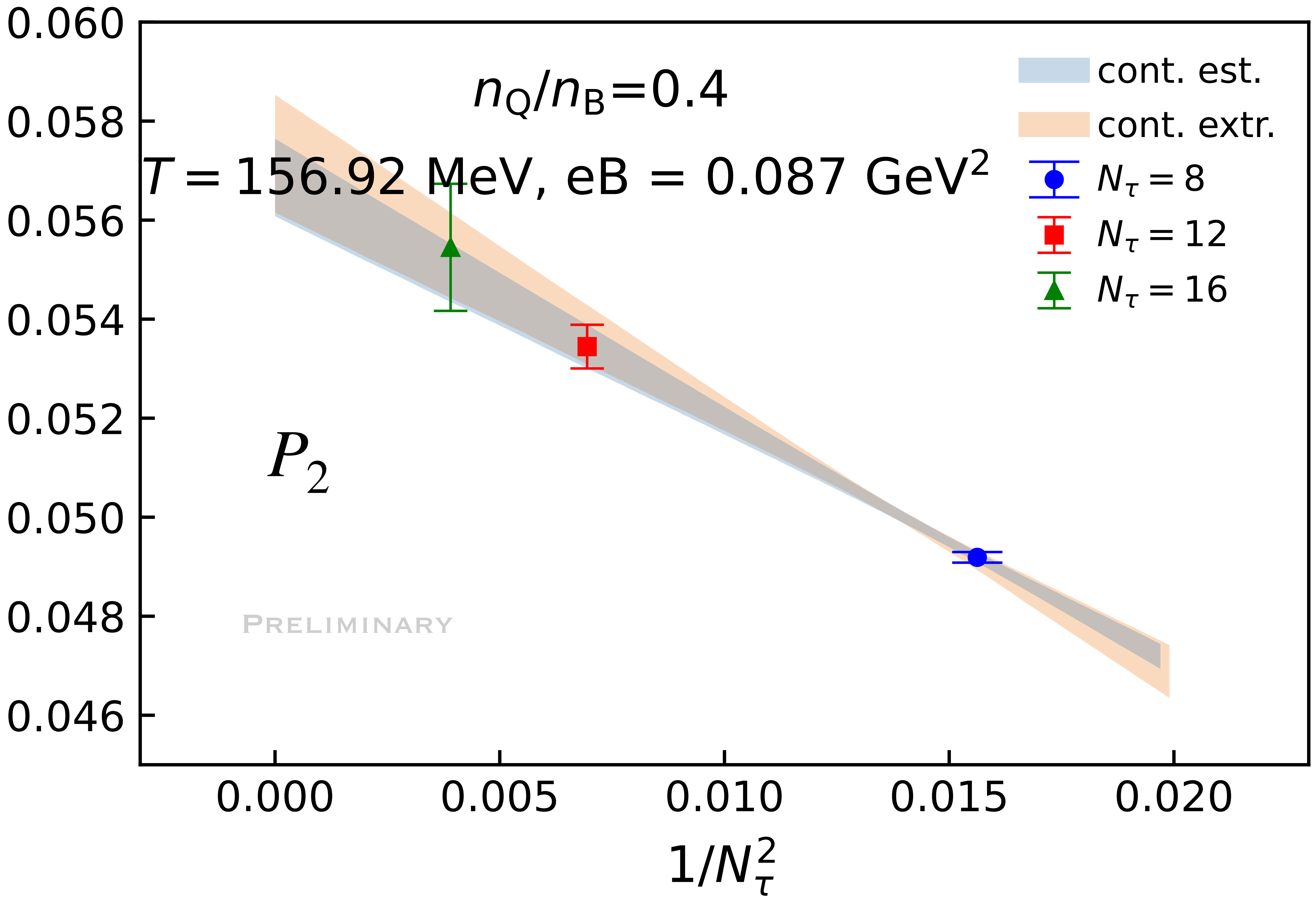


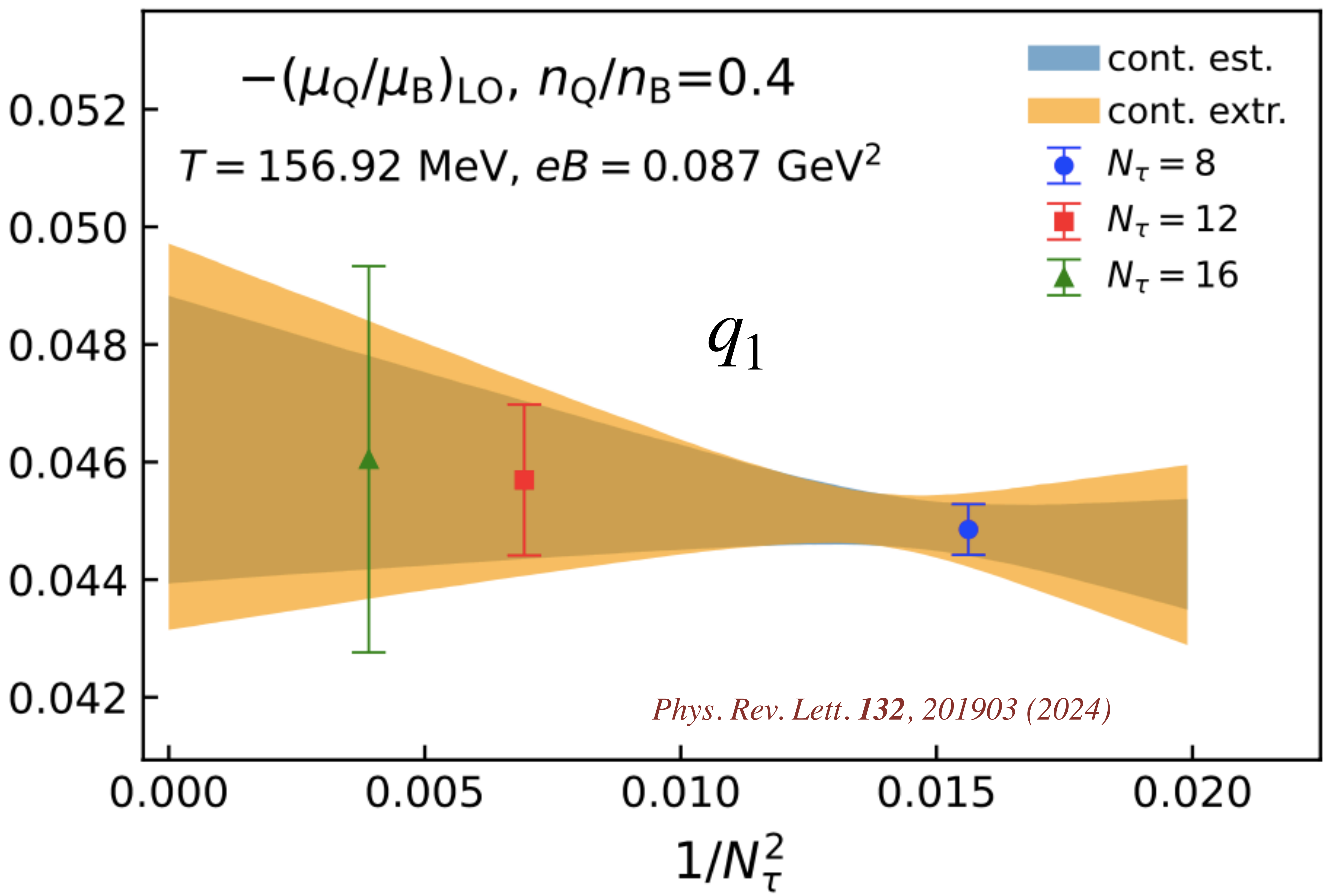
B. Continuum estimates



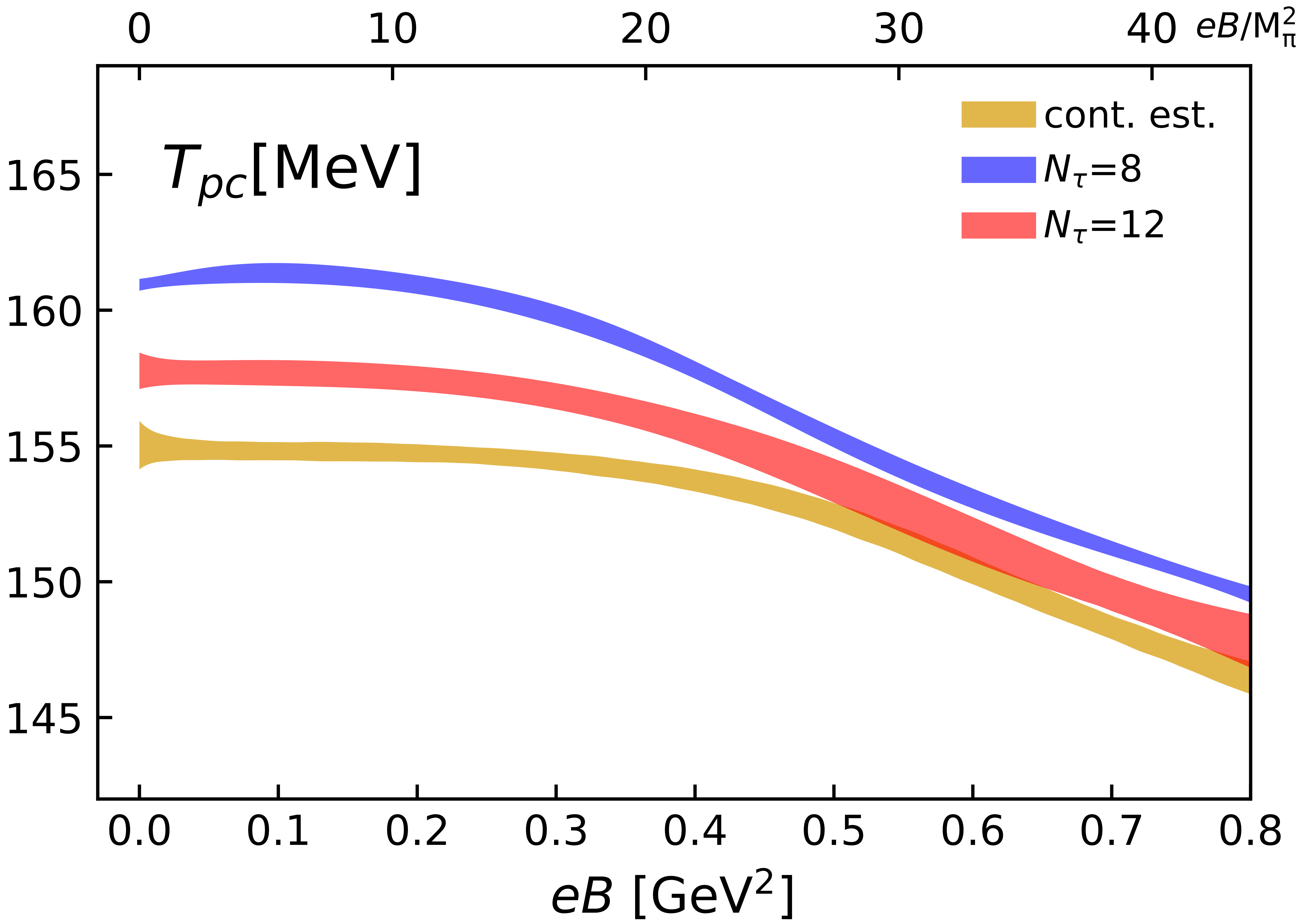


Continuum Estimates vs Extrapolations





Transition Line and Chiral Susceptibility



H.-T. Ding, J.-B. Gu, **AK**, S.-T. Li, **PRD** 111 (2025) 11, 114522

Peak location of $\chi_M \;\to\; T_{pc}(eB)$

$$M = \frac{1}{f_K^4}\Big[m_s\left(\langle\bar\psi\psi\rangle_u + \langle\bar\psi\psi\rangle_d\right) - \left(m_u + m_d\right)\langle\bar\psi\psi\rangle_s\Big]$$

$$\begin{aligned}\chi_M &= m_s\left(\partial_{m_u} + \partial_{m_d}\right) M\Big|_{m_u=m_d=m_l} \\ &= \frac{1}{f_K^4}\left[m_s\left(m_s\chi_l - 2\langle\bar\psi\psi\rangle_s - 4m_l\chi_{su}\right)\right],\end{aligned}$$

Next-to-leading order

Ongoing work: insights on next-to-leading order contributions.

n^{B} dominant to Δp (factor ~ 2)

Interestingly as eB grows contributions reduce drastically.