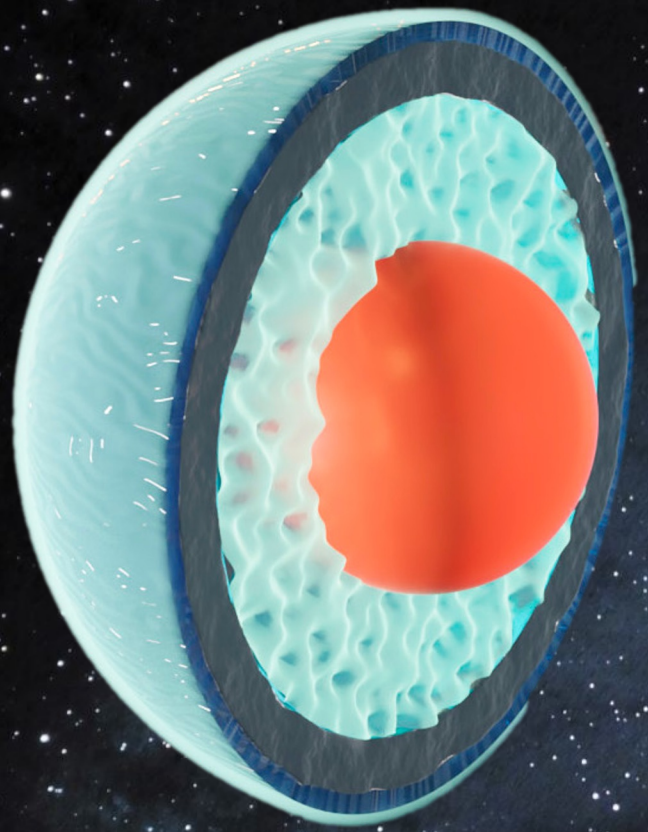
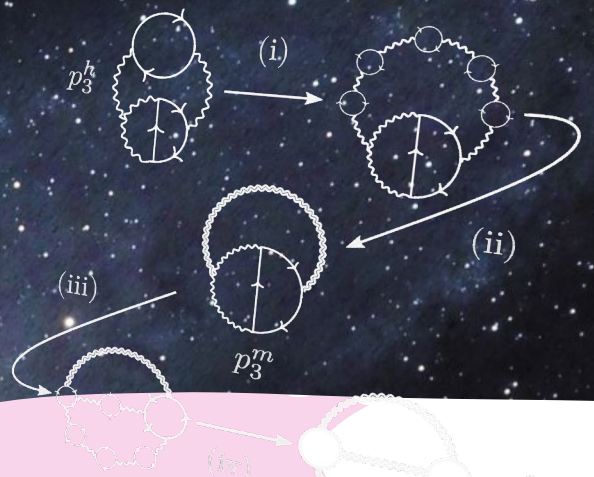




How pQCD constrains the EoS at NS densities?

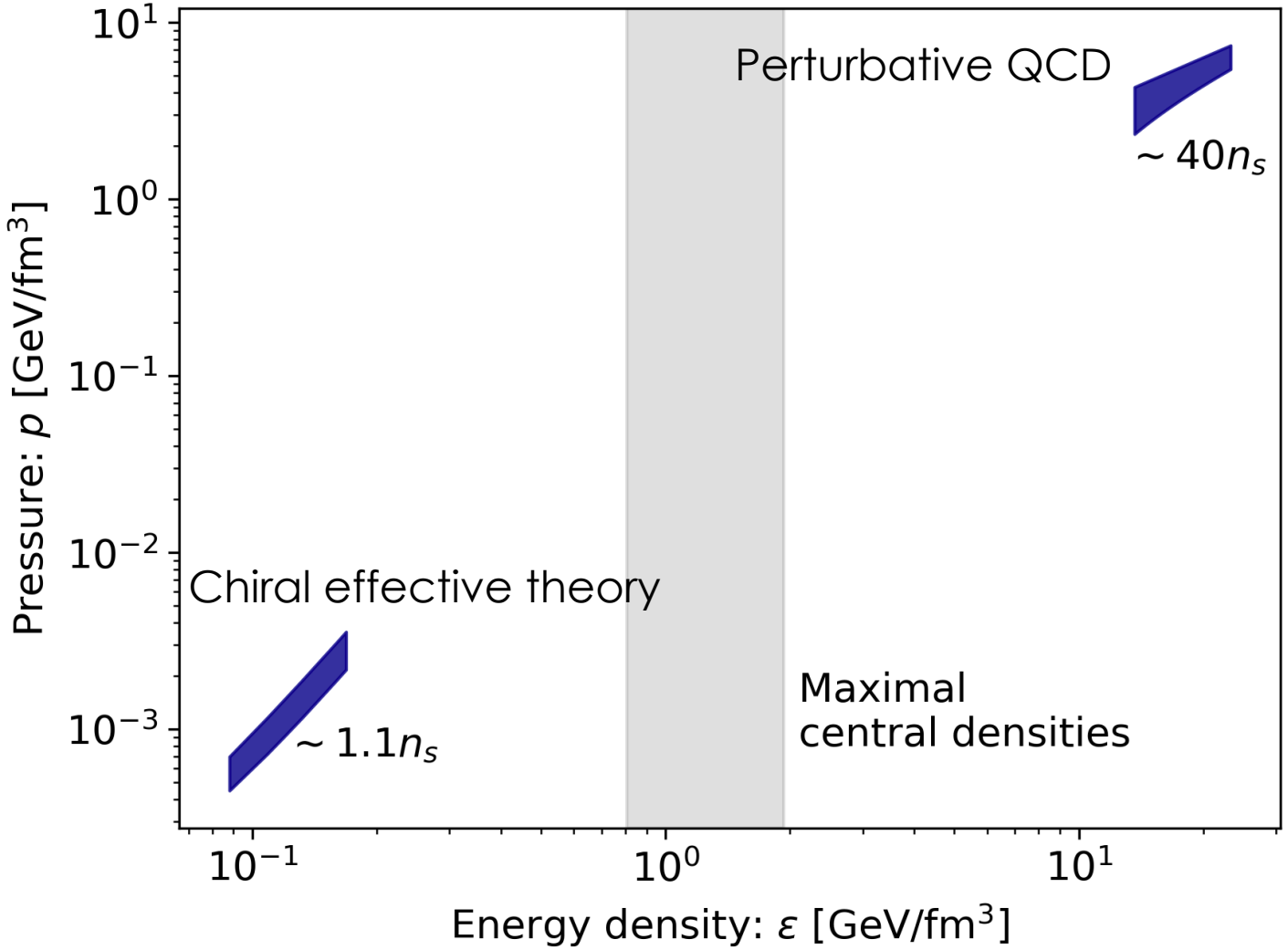
THIS TALK: HOW PQCD CONSTRAINS THE EQUATION OF STATE AT NEUTRON STAR DENSIT*IES*

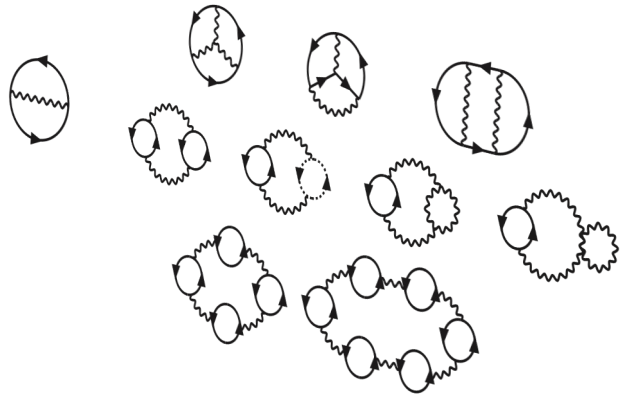
KOMOLTSEV & AK, PRL128 (2022) 20, 2111.05350

TYLER'S TALK: AB-INITIO QCD CALCULATIONS IMPACT THE INFERENCE OF NEUTRON-STAR EQUATION OF STATE

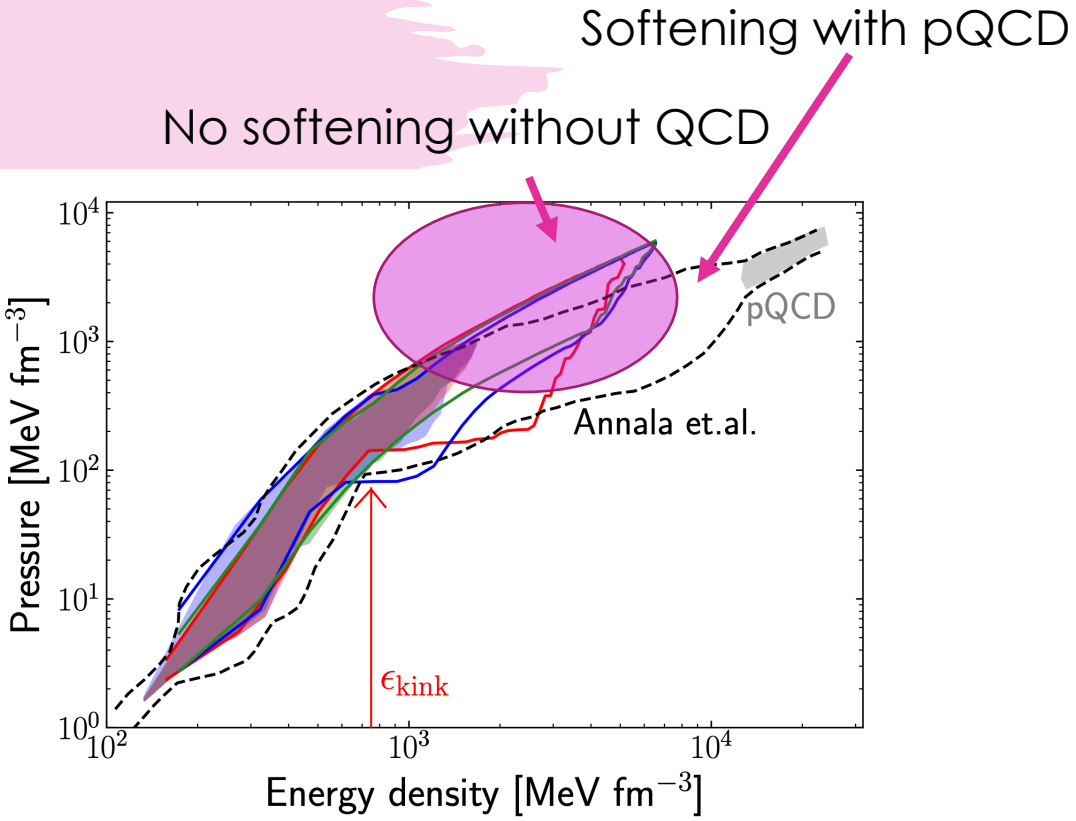
GORDA, KOMOLTSEV & AK 2204.11877

How pQCD constrains EoS at low densities:



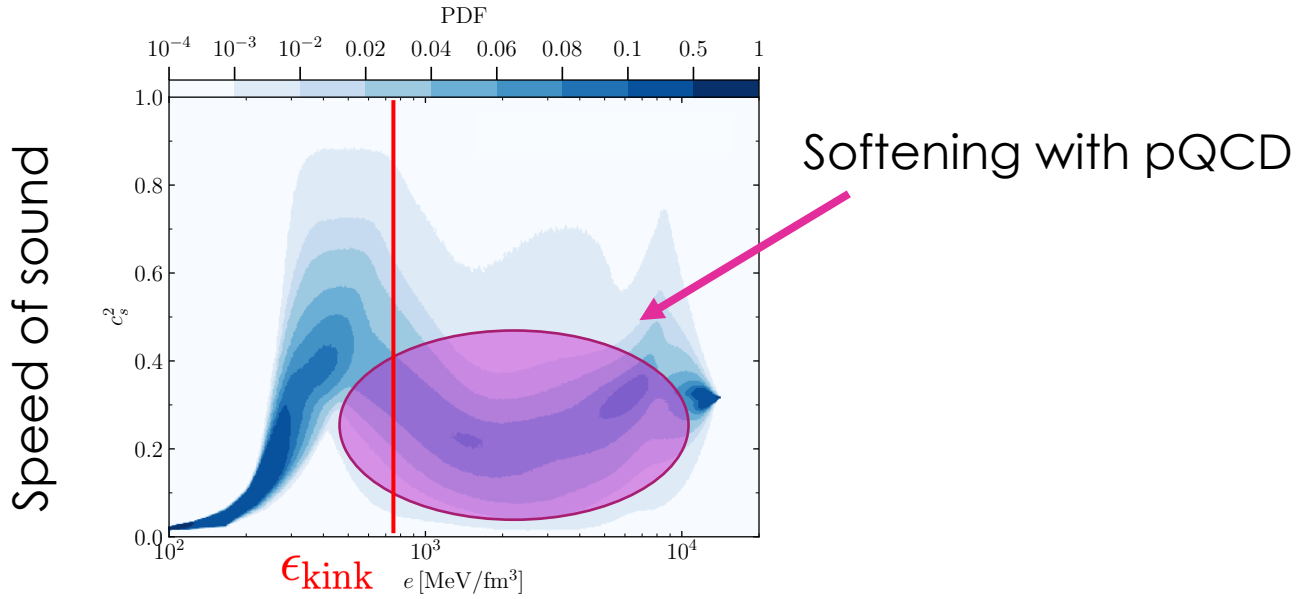


Freedman, McLerran, PRD 16 (1977)
Kurkela et al. PRD 81 (2010)
Kurkela, Vuorinen PRL 117 (2016)
Gorda et al. PRL 121 (2018)
Gorda et al. PRD 104 (2021)
Gorda et al. PRL 127 (2021)
Gorda et al. 2204.11893

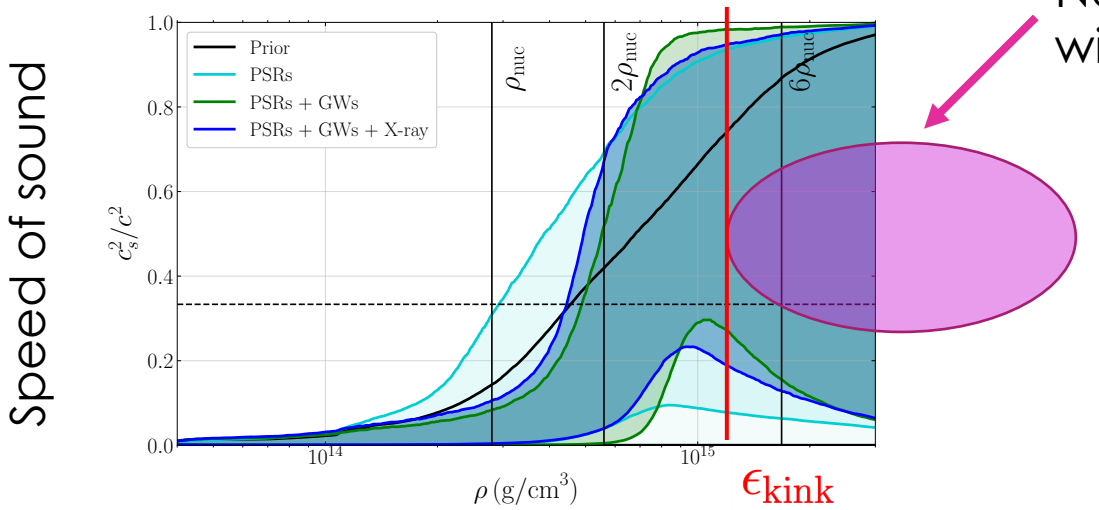


Annala, Gorda, Kurkela, Nätttilä, Vuorinen Nature Physics 16 (2020) 9
Somasundaram, Tews, Margueron 2112.08157

- Softening seen (only) in works using pQCD
- Softening interpreted as formation of Quark Matter



Altiparmak, Ecker, Rezzolla 2112.08157
Also: Han, Huang, Tang & Yi-Zhong Fan 2207.13613,
Marczenko, McLerran, Redlich & Sasaki 2207.13059



Landry, Essick, Chatziioannou PRD 101 (2020)

How pQCD constrains EoS at low densities:

- **Why** does QCD at $40n_s$ constrain the EoS at NS densities:

How pQCD constrains the equation of state at neutron star densities

Komoltsev & AK, PRL128 (2022) 20, 2111.05350

- **How** QCD affects EoS infrerence

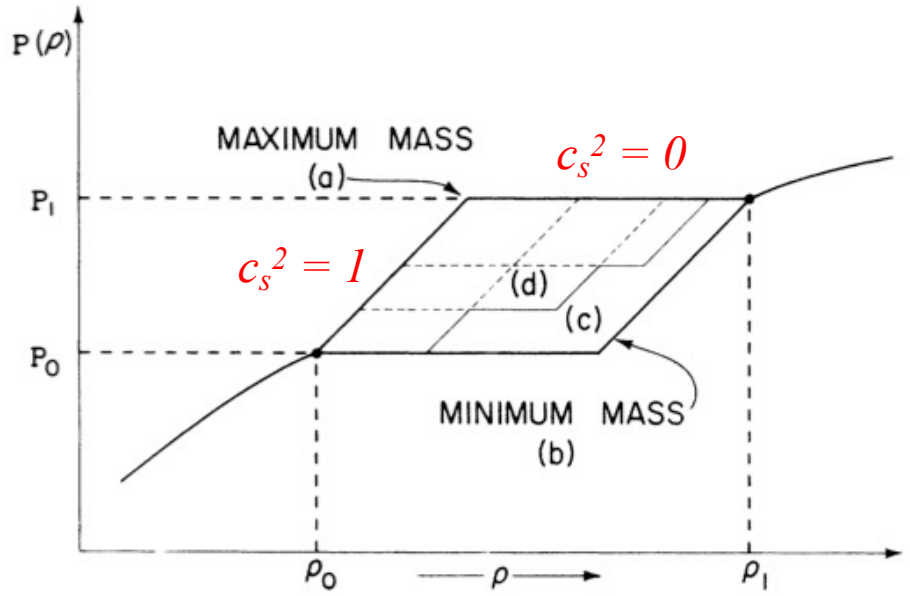
Ab-initio QCD calculations impact the inference of neutron-star equation of state

Gorda, Komoltsev & AK 2204.11877

Robust EoS constraints:

General considerations:

- Mechanical stability: $c_s^2 > 0$
- Causality: $c_s^2 < 1$



Rhoades & Ruffini, Phys.Rev.Lett. 32 (1974)
Lope-Oter, Windisch, Llanes-Estrada, Alford, *J. Phys. G (2019)*
Lope-Oter, Llanes-Estrada, EPJA 58 (2022)

Robust EoS constraints:

General considerations:

- Mechanical stability: $c_s^2 > 0$
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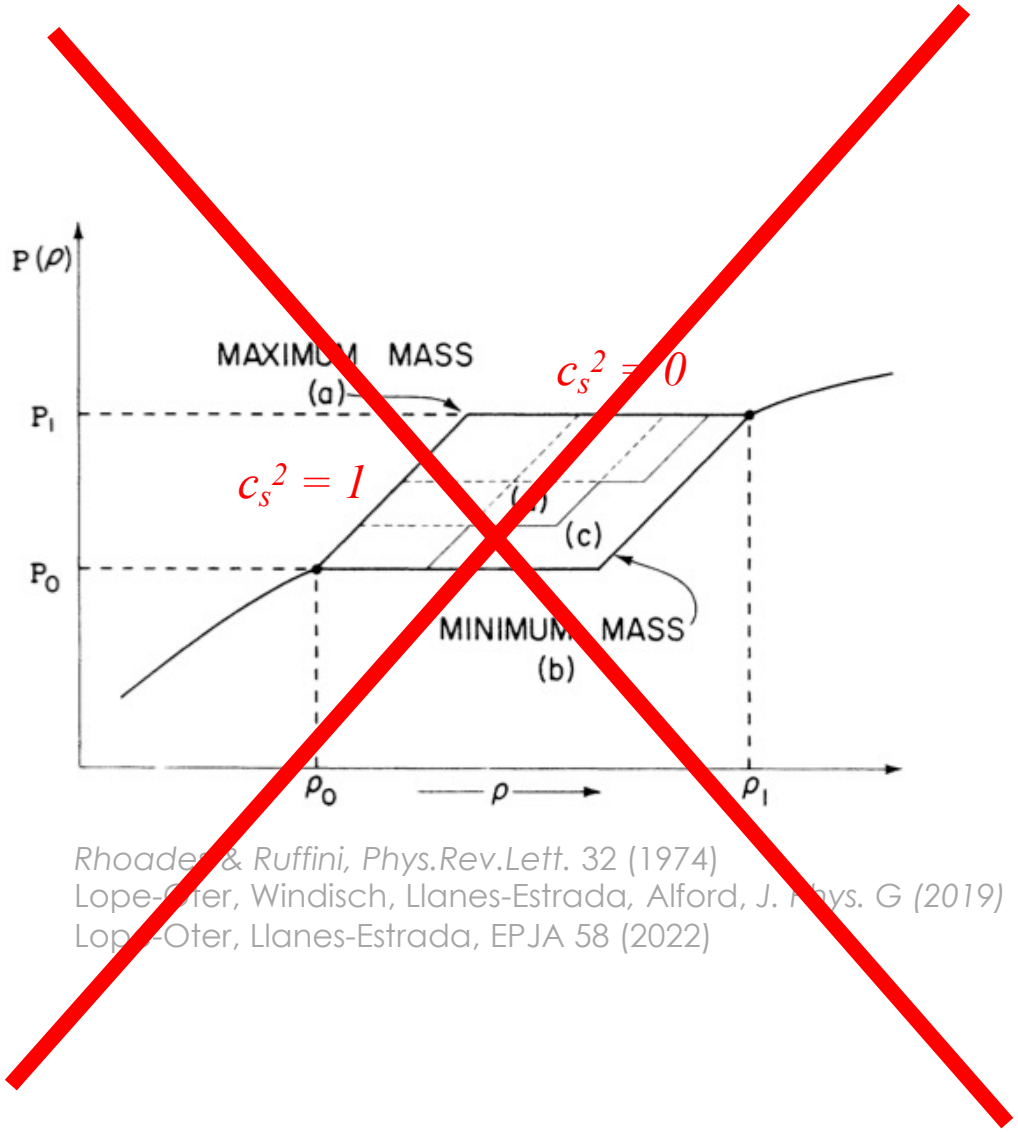
- Consistency:

$$P(\epsilon) \ vs. \ \Omega(\mu)$$

Reduced EoS

Full EoS

Information of $\{P, \epsilon, n\}$



Rhoades & Ruffini, *Phys.Rev.Lett.* 32 (1974)
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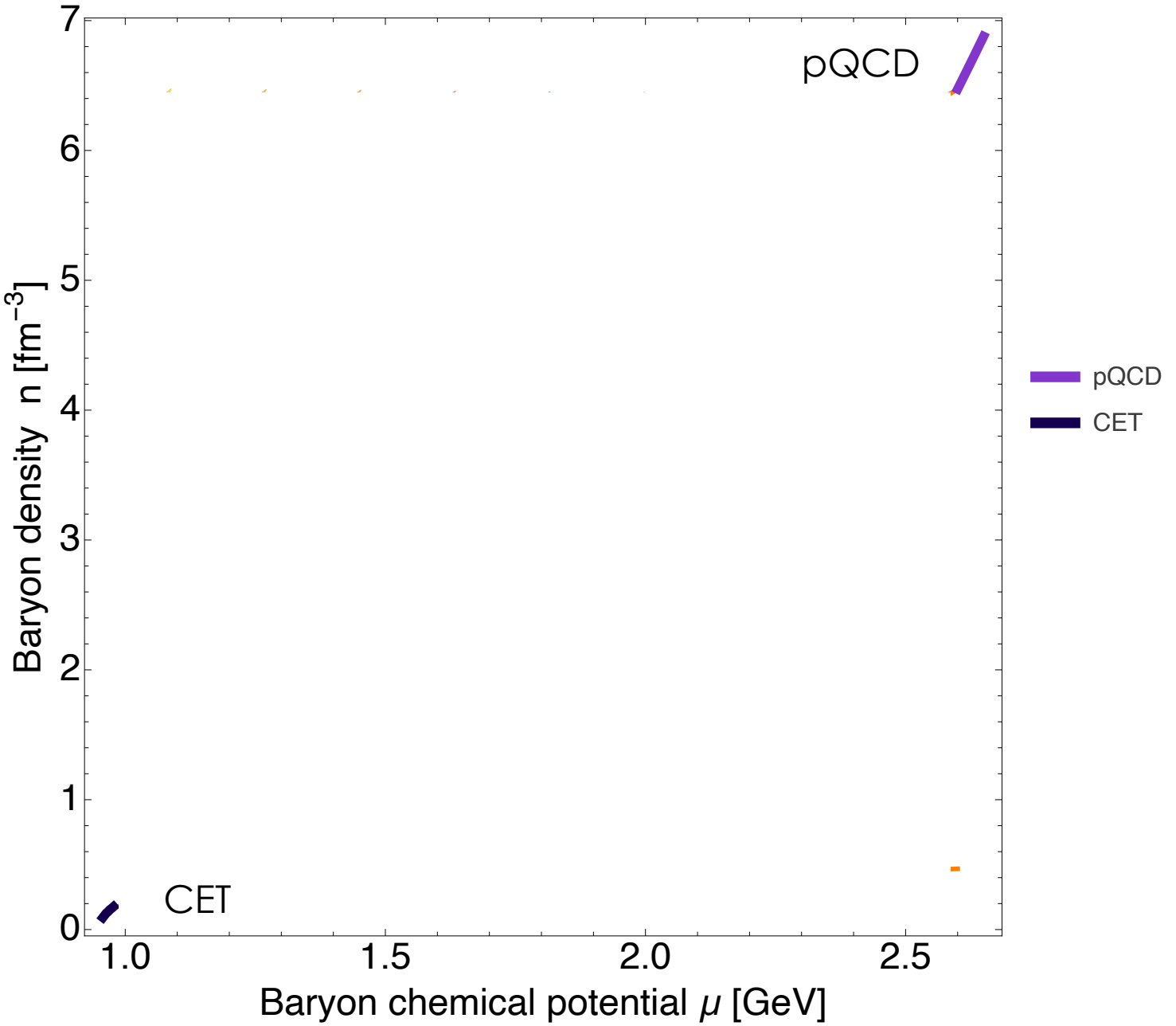
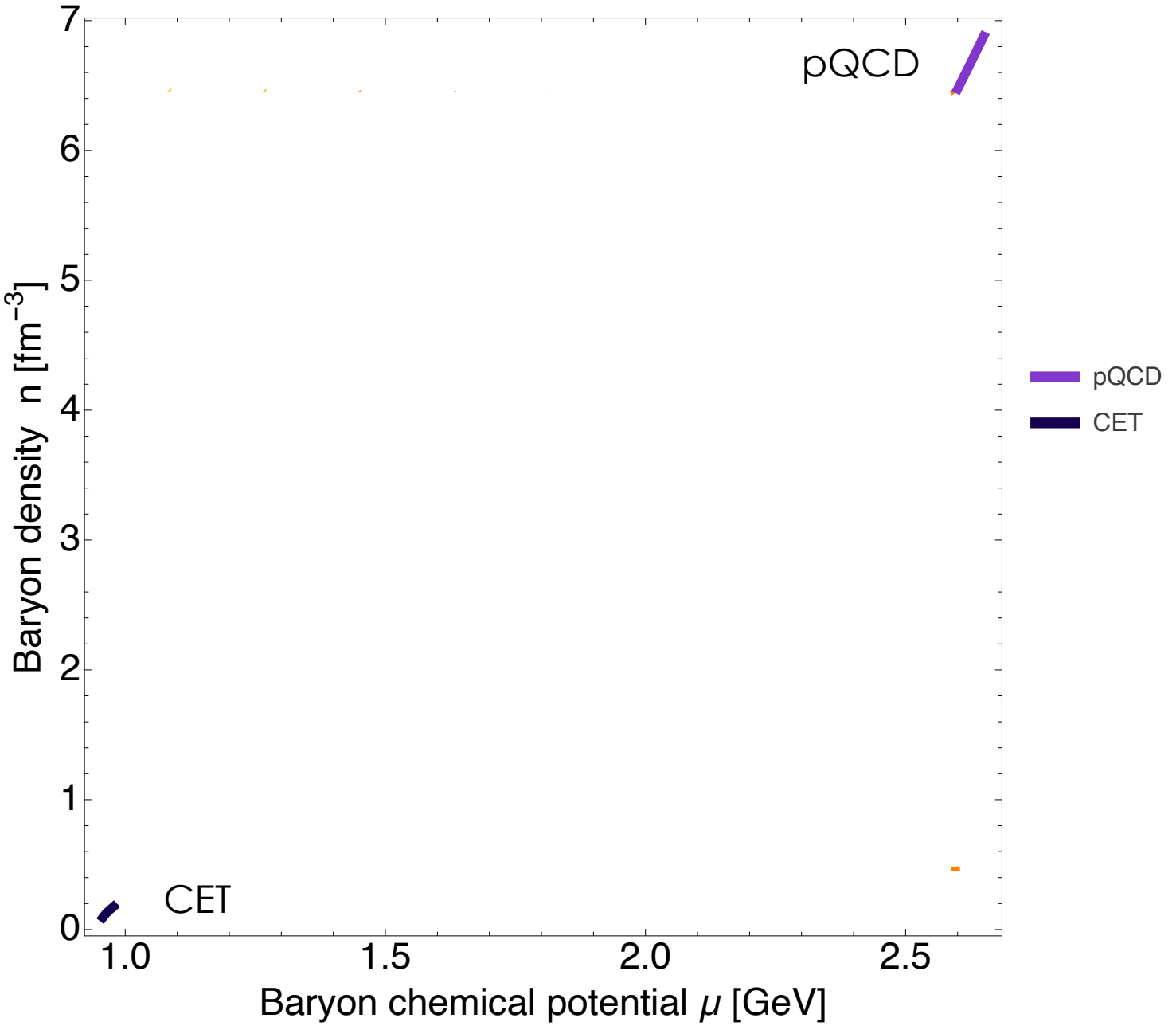


Komoltsev & AK, PRL128 (2022)

Setup:

- Stability

$$\partial_\mu^2 \Omega(\mu) \leq 0 \quad \Rightarrow \quad \partial_\mu n(\mu) \geq 0$$



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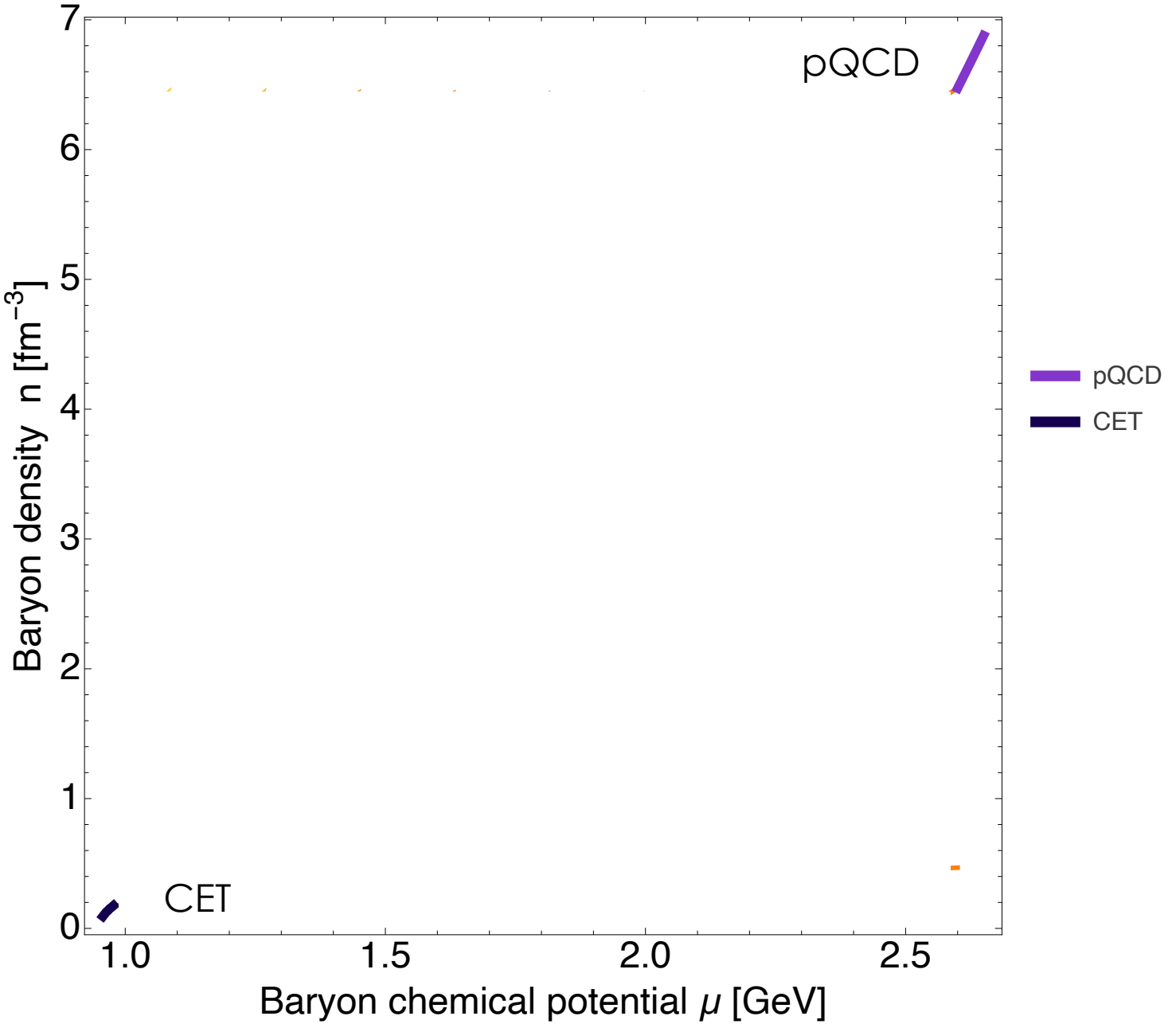

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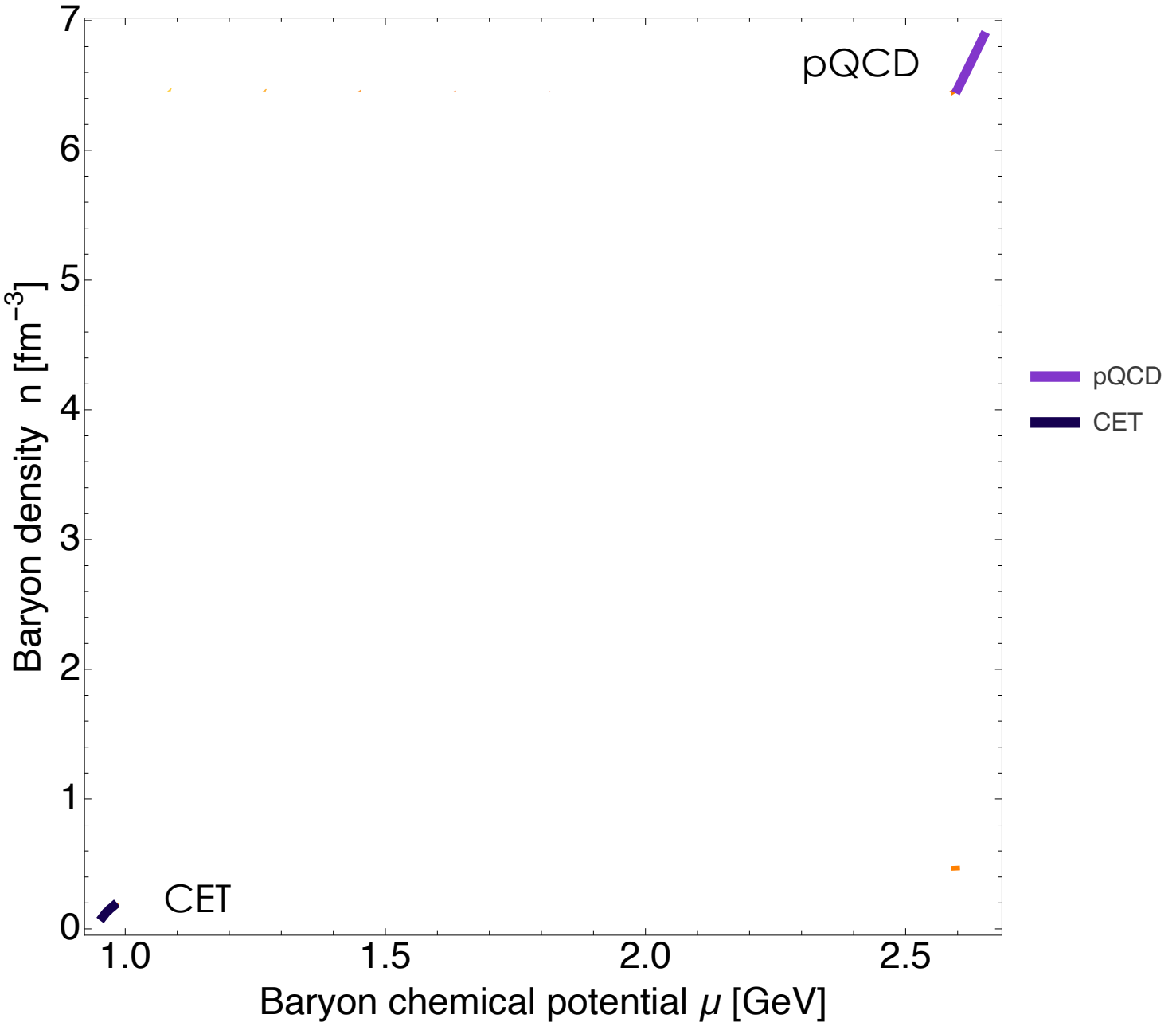
- Consistency

$$\int_{\mu_{CET}}^{\mu_{QCD}} n(\mu)\, d\mu = p_{QCD} - p_{CET} = \Delta p$$



Komoltsev & AK, PRL128 (2022)

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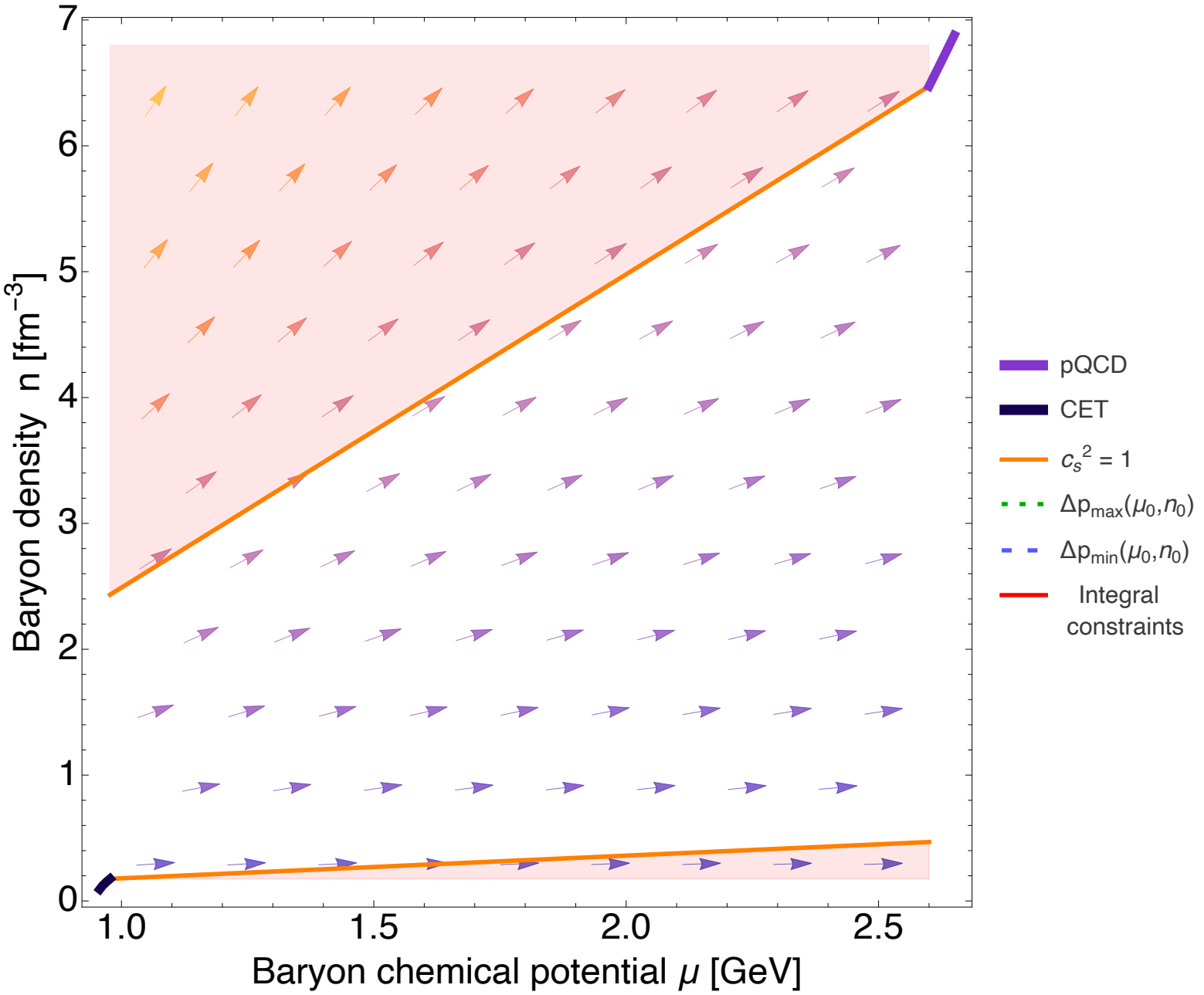

Komoltsev & AK, PRL128 (2022)

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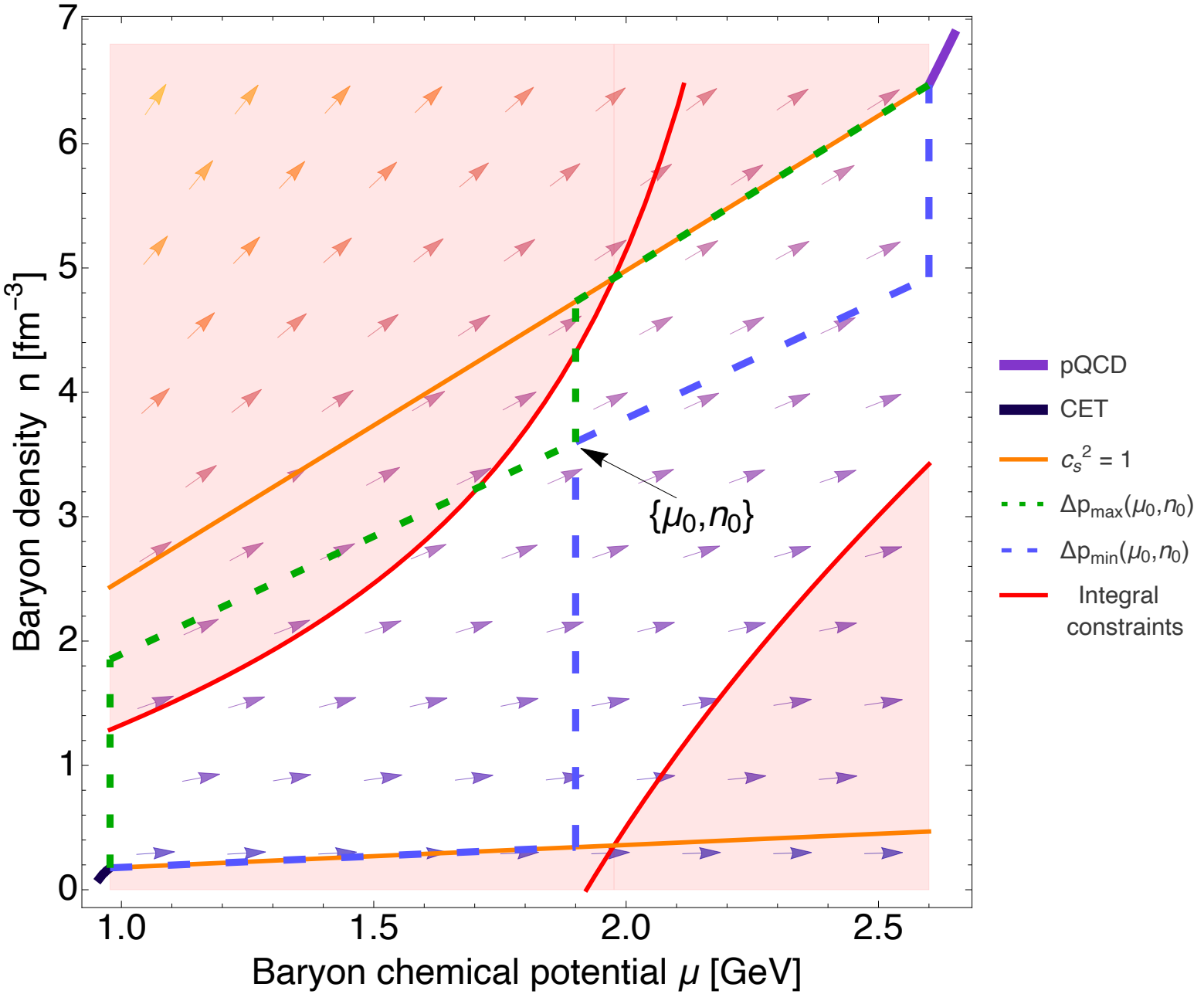

Komoltsev & AK, PRL128 (2022)

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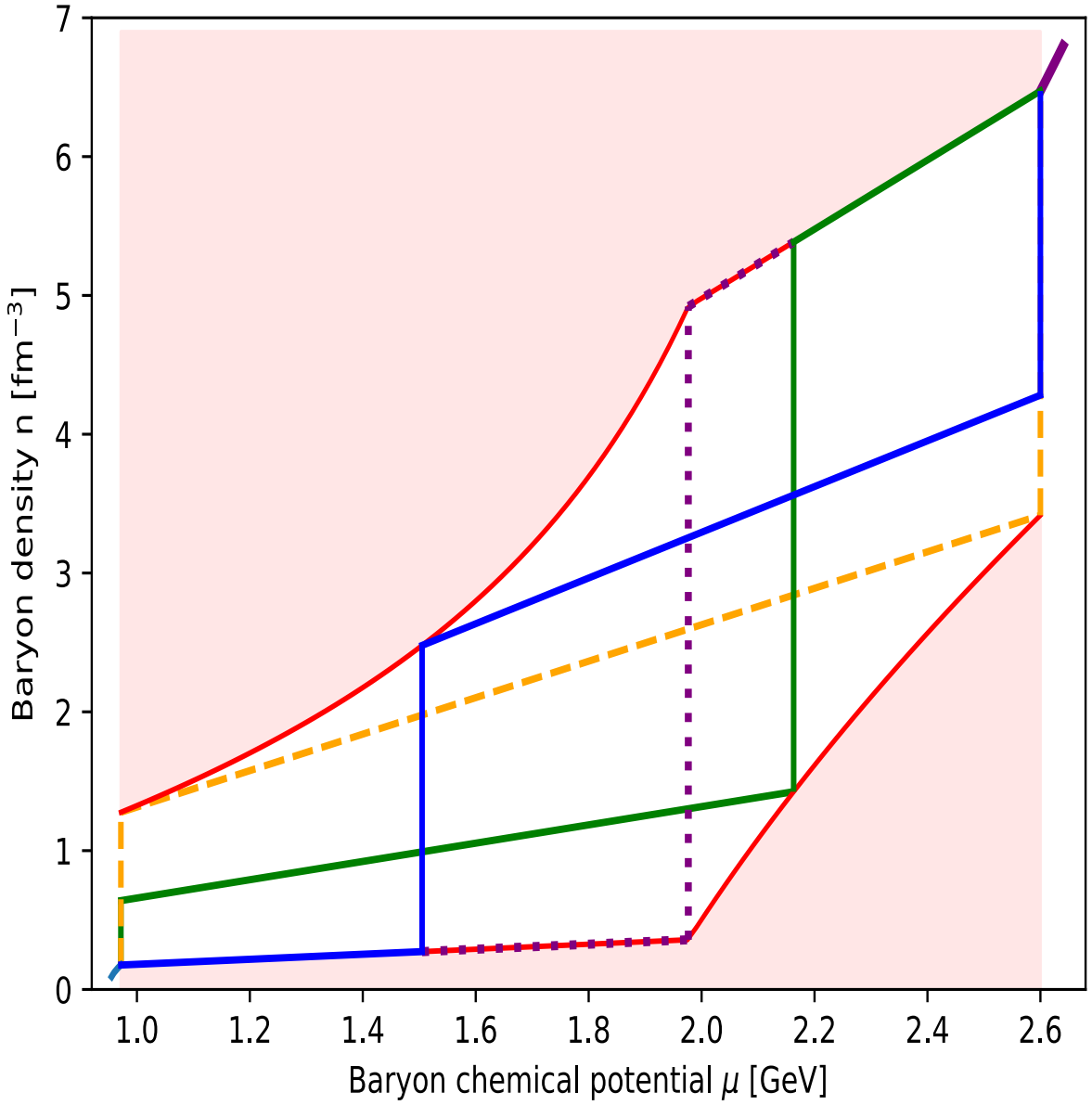
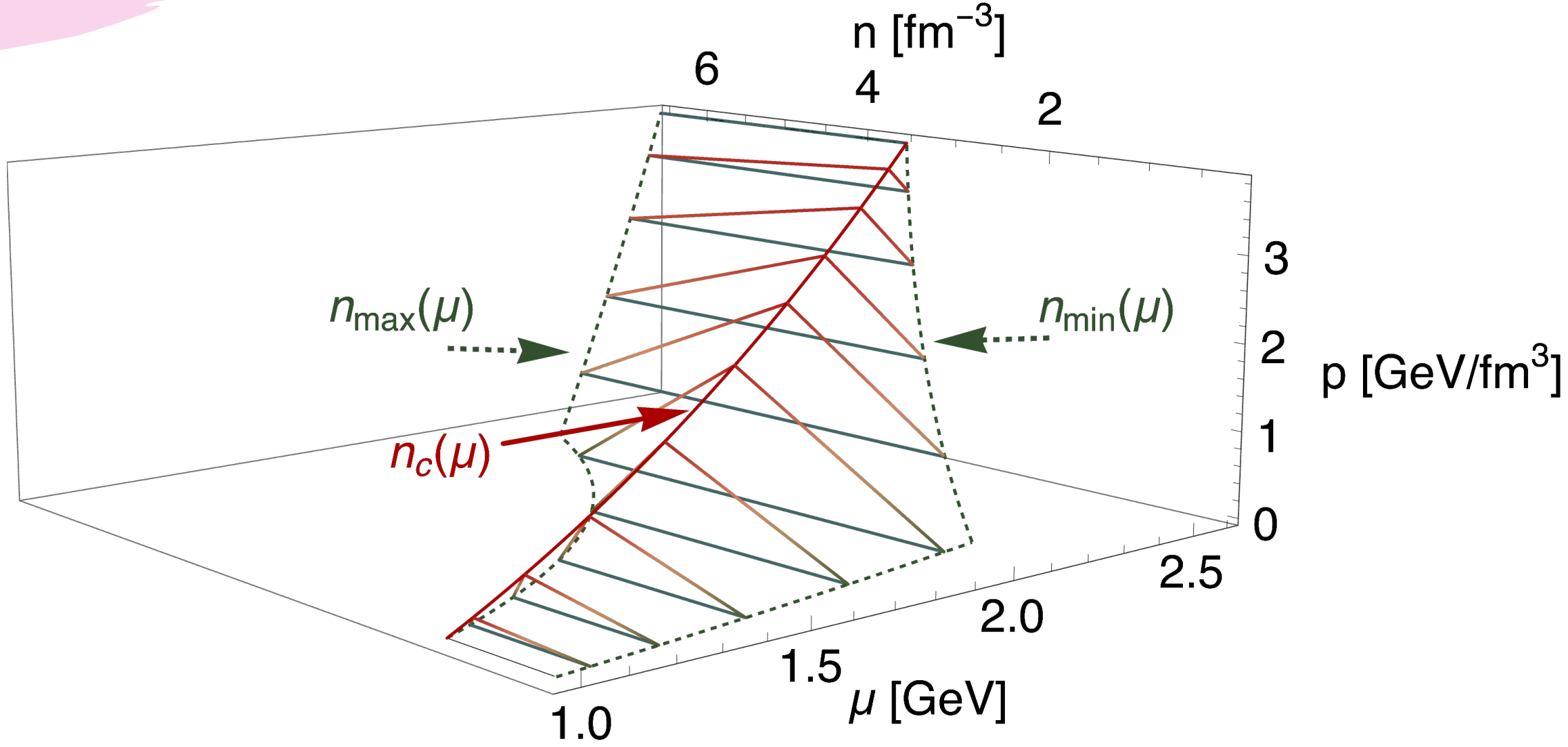


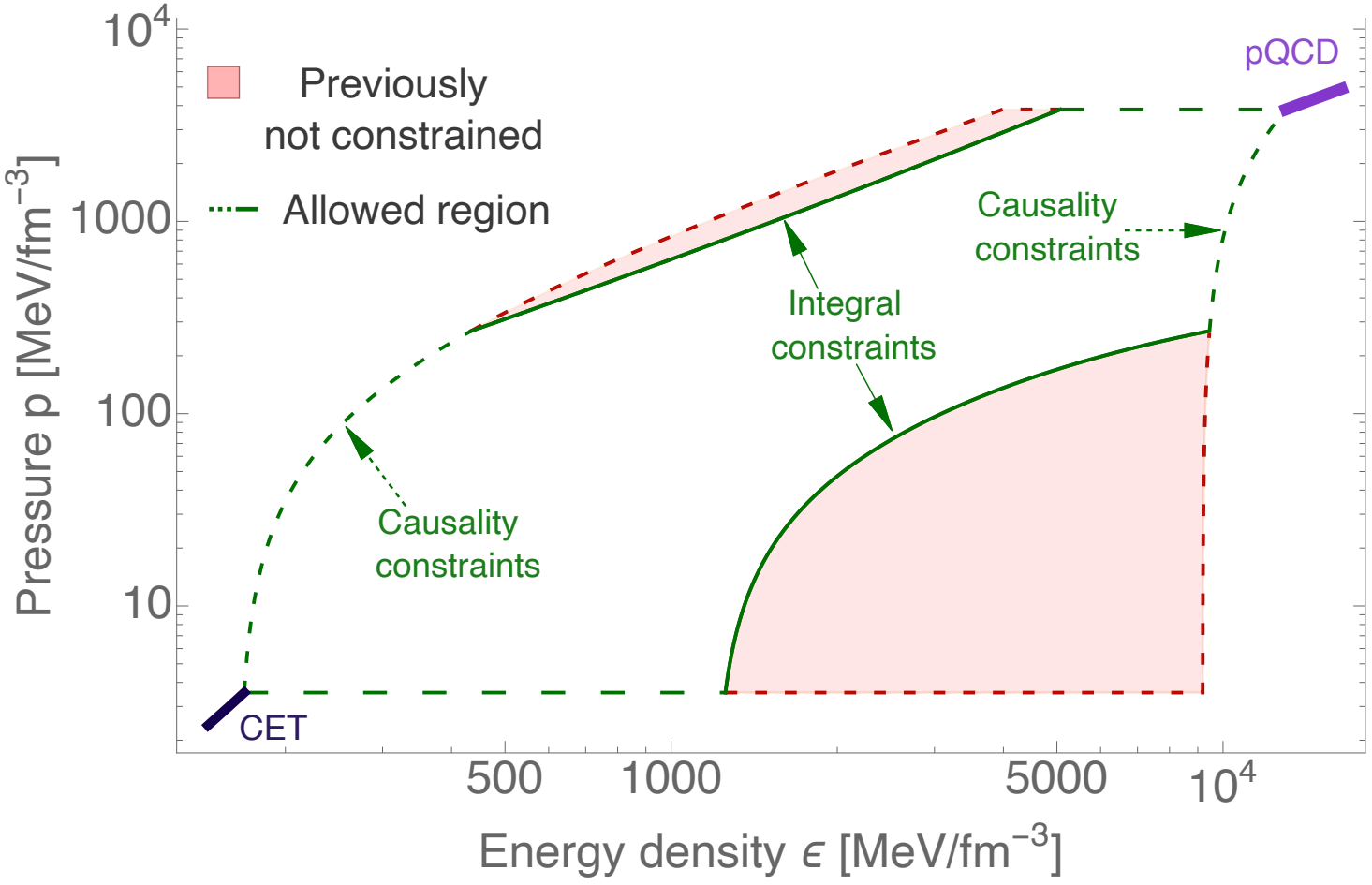
Komoltsev & AK, PRL128 (2022)

Mapping to $\epsilon - p$ -plane



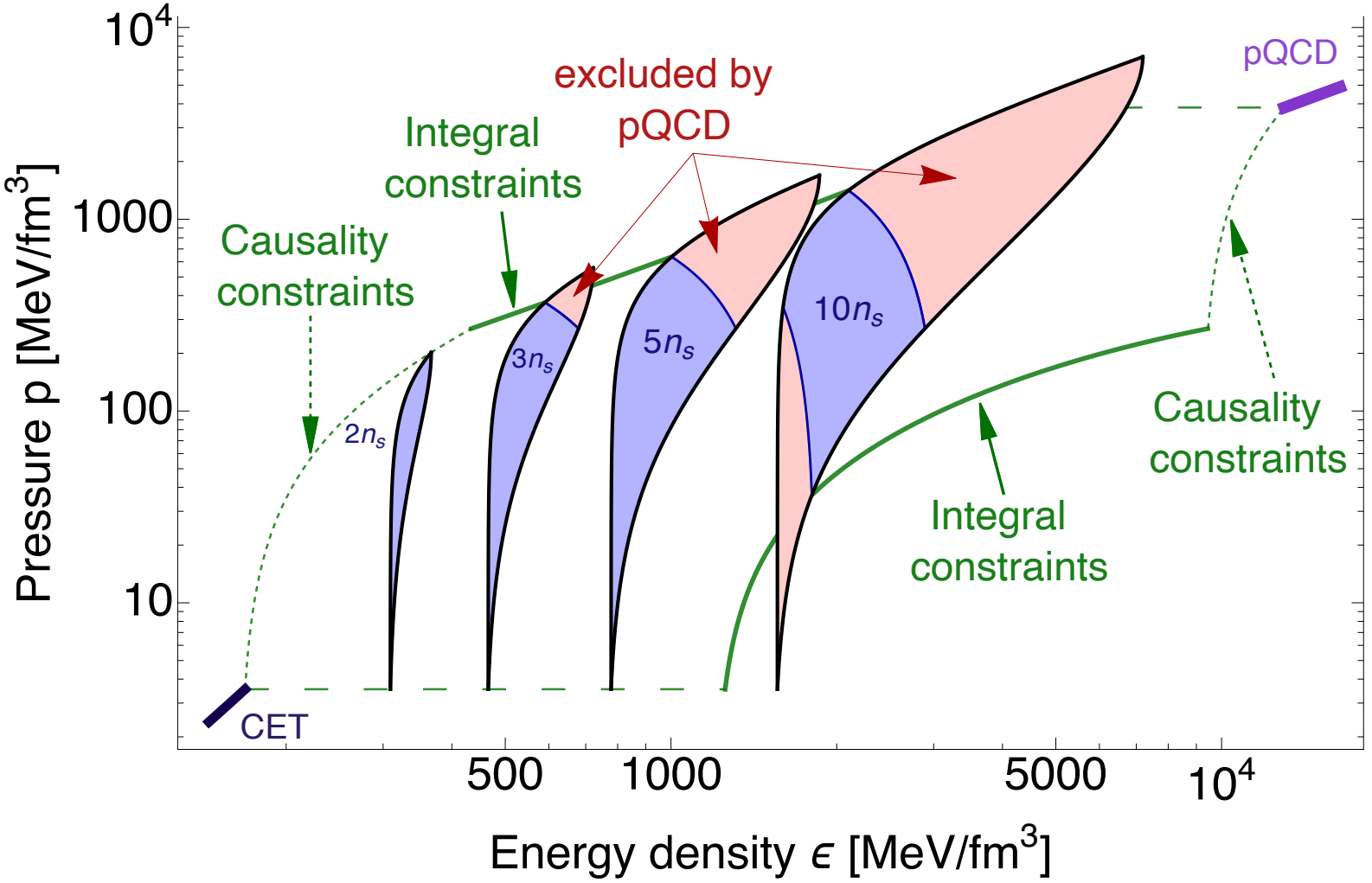
Komoltsev & AK, PRL128 (2022)

Mapping to $\epsilon - p$ -plane



Komoltsev & AK, PRL128 (2022)

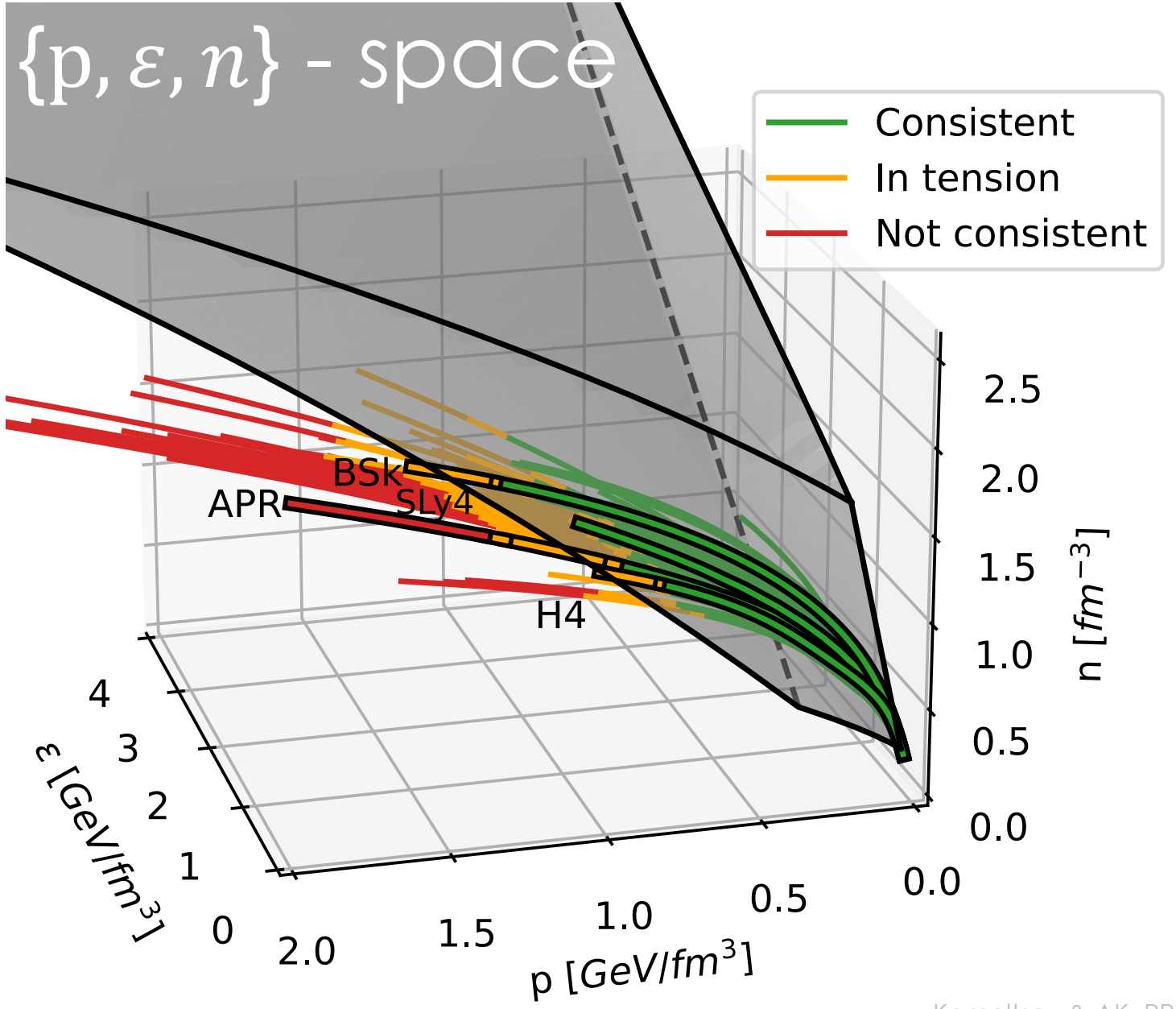
Constraints for fixed n on $\epsilon - p$ -plane



Komoltsev & AK, PRL128 (2022)

Constraints in $\{p, \varepsilon, n\}$ - space

Models from CompOSE database



Komoltsev & AK, PRL128 (2022)

Conclusions:

- $\{n, p, \varepsilon\}$ carries more information than $p(\varepsilon)$
- Stability, causality and consistency
- QCD at $n = 40\ n_s$ offers a robust constraint down to $n = 2.3\ n_s$
- Systematics complementary. No model uncertainties

No transport models, no stellar models, no extrapolation in proton fraction, no GR …
Can be used as baseline for BSM and beyond-GR, Lope-Oter, et al, J. Phys. G (2019)

HOW QCD affects the EoS inference: Tyler Gorda's talk