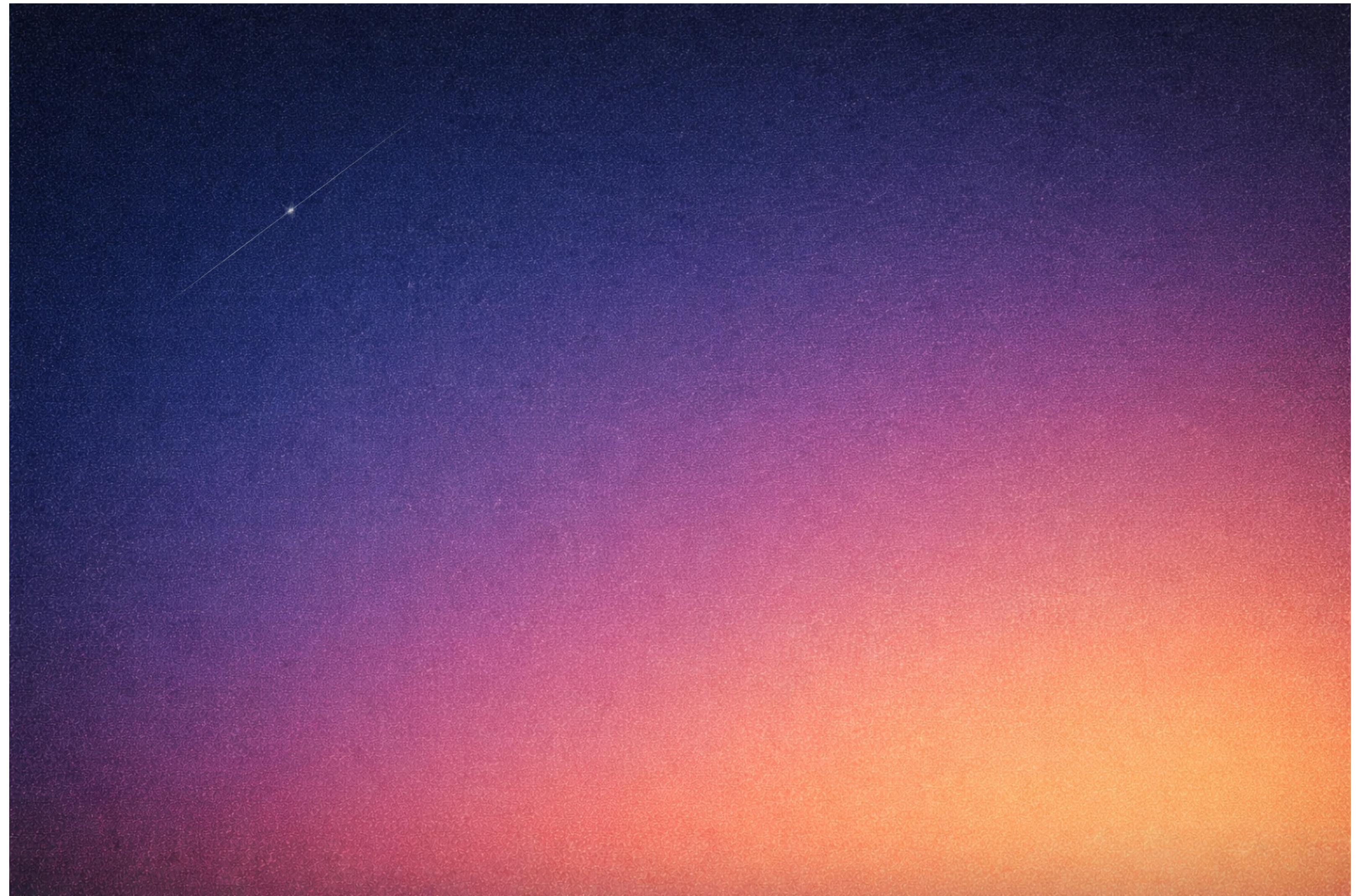


First-principles motivated prior for neutron-star equation-of-state inference

Oleg Komoltsev

SEWM

August 2026



THE ASTROPHYSICAL JOURNAL

OPEN ACCESS

Constrained Gaussian-process-bridge Prior for Neutron-star Equation-of-state Inference

Tyler Gorda, Oleg Komoltsev, Aleksi Kurkela, and Eirik Sunde

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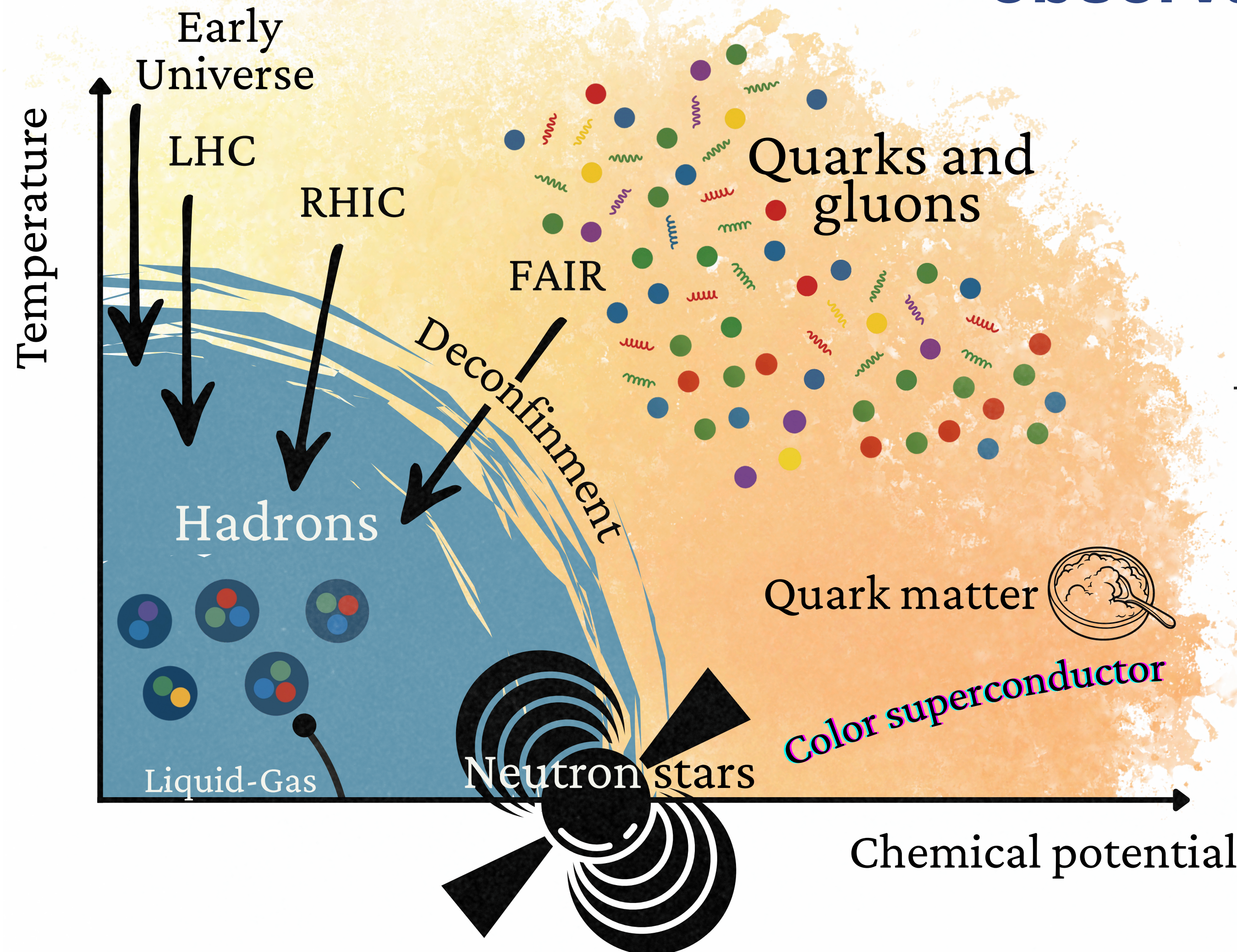
[The Astrophysical Journal](#), [Volume 1002](#), [Number 1](#)

Citation Tyler Gorda *et al* 2026 *ApJ* **1002** 40

DOI 10.3847/1538-4357/ae552a



QCD phase diagram



observations

$$(m, r, \Lambda)$$

to v & love

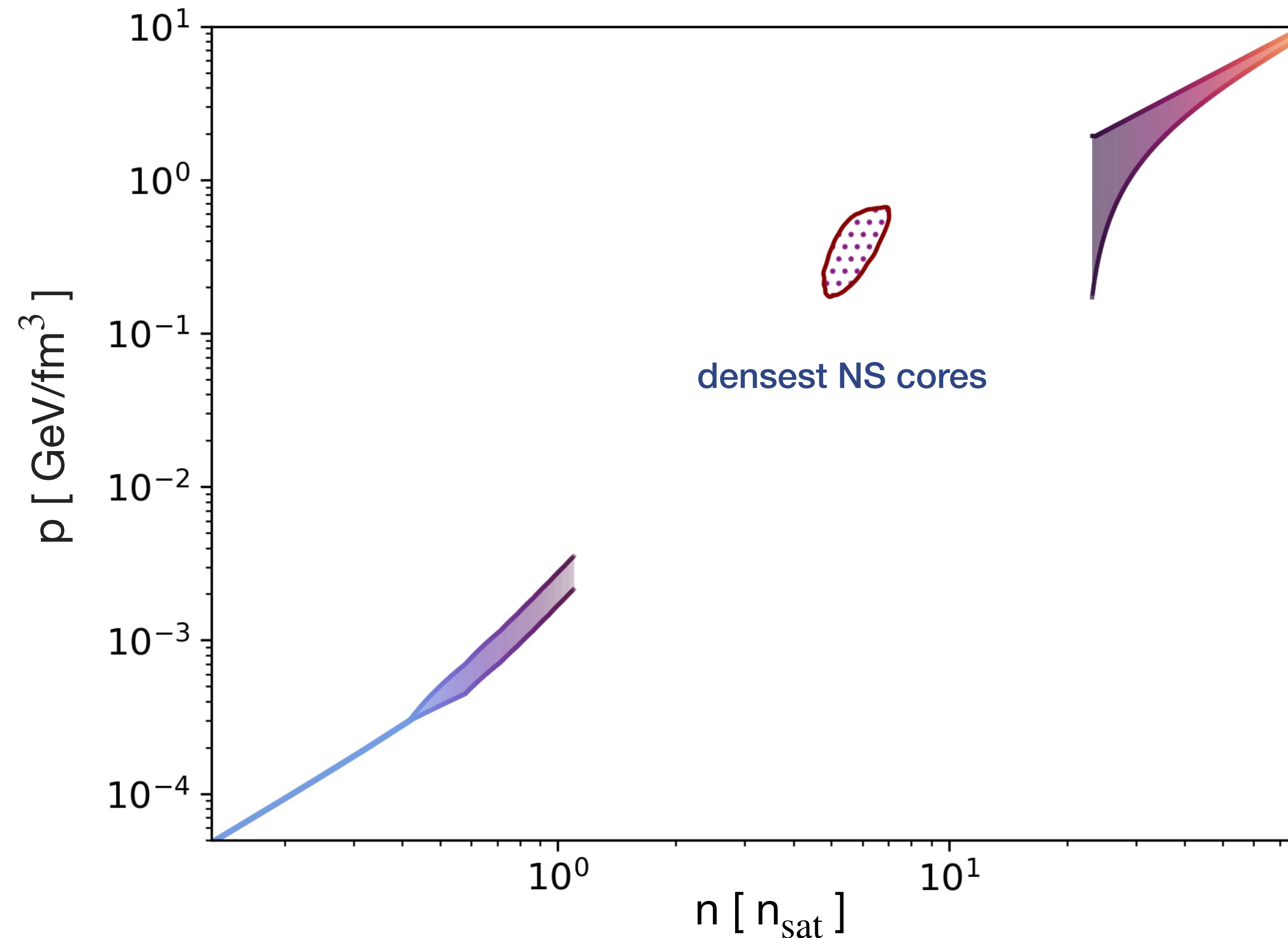
$$\frac{dp}{dr} = -\frac{Gm}{r^2} \varepsilon \left(1 + \frac{p}{\varepsilon} \right) \left(1 + \frac{4\pi r^3 \varepsilon}{m} \right) \left(1 - \frac{2Gm}{r} \right)^{-1}$$

$$\frac{dm}{dr} = 4\pi r^2 \varepsilon \quad \frac{d\Lambda}{dr} = f(r, \varepsilon, p)$$

equation of state

$$p(\varepsilon)$$

EoS from the first principles



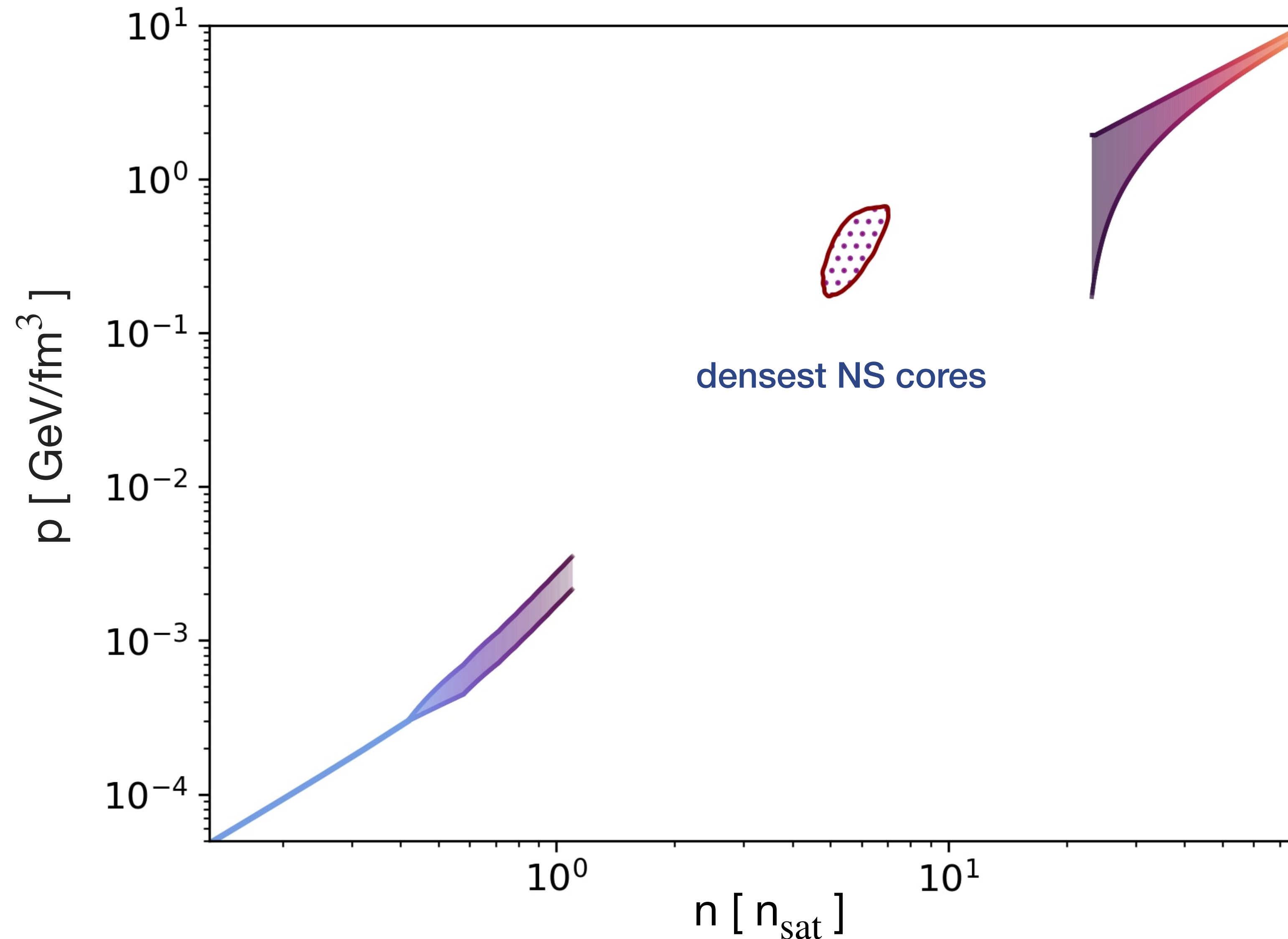
perturbative QCD
(pQCD)

Gorda, Kurkela et.al.
Phys. Rev. Lett. 127, 162003

chiral effective
field theory (cEFT)

Hebeler, Lattimer et.al.
ApJ 773 11

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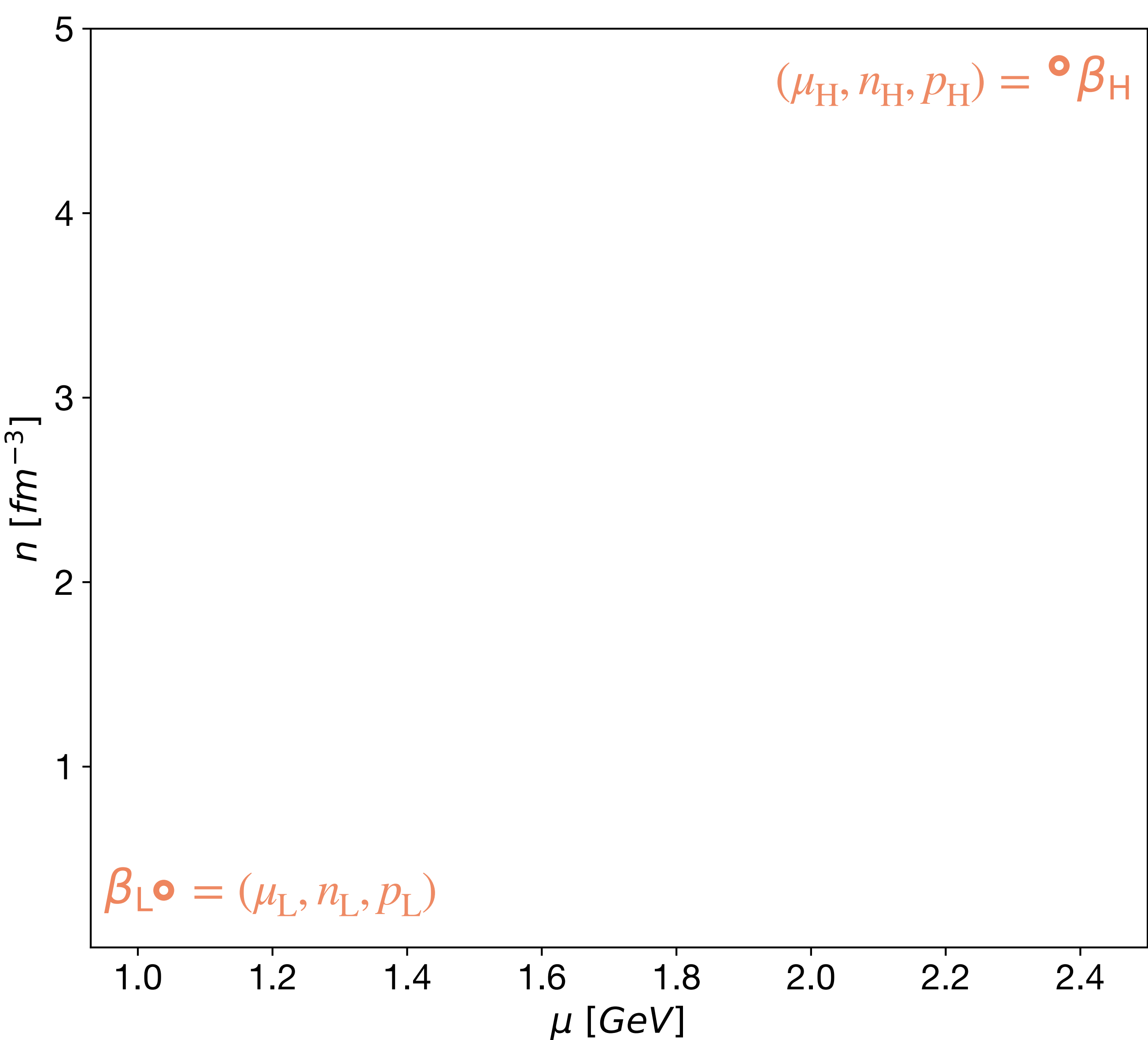
Gorda, Kurkela et.al.
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polytropic interpolation
 c_s^2 segments
Gaussian processes
GPB ← this talk

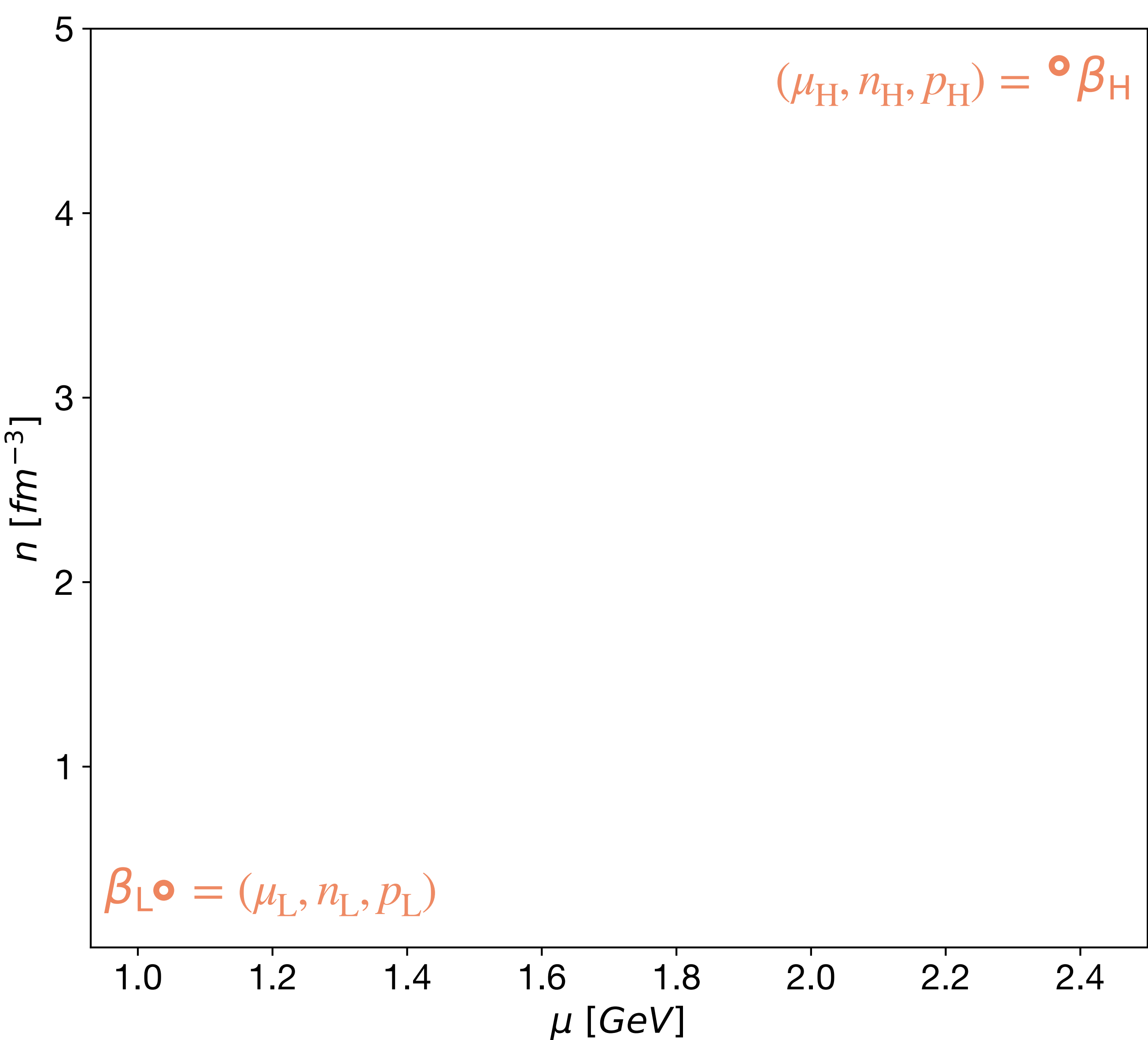
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self-similar [fractal] EoS



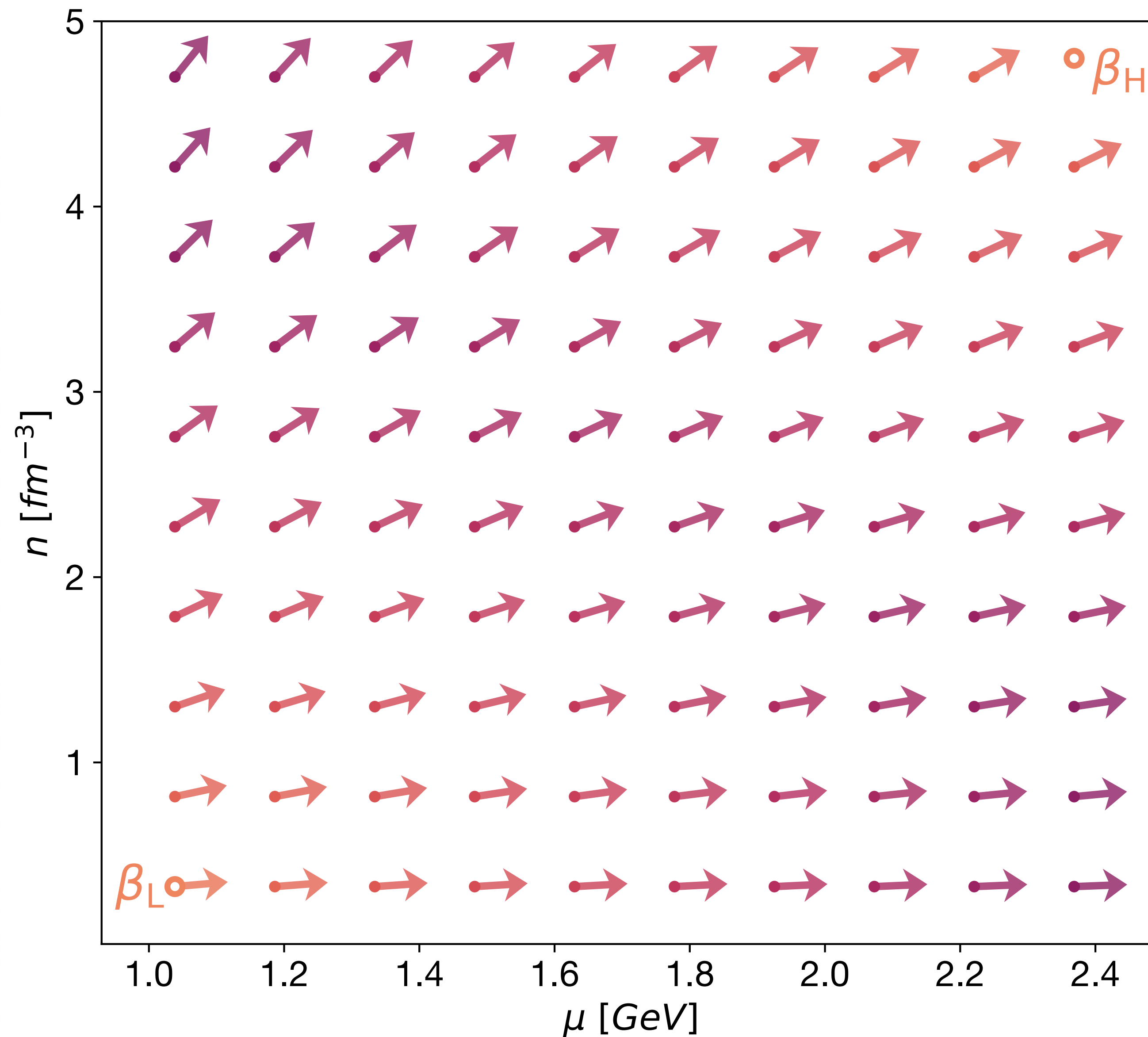
self-similar [fractal] EoS



stability

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

self-similar [fractal] EoS



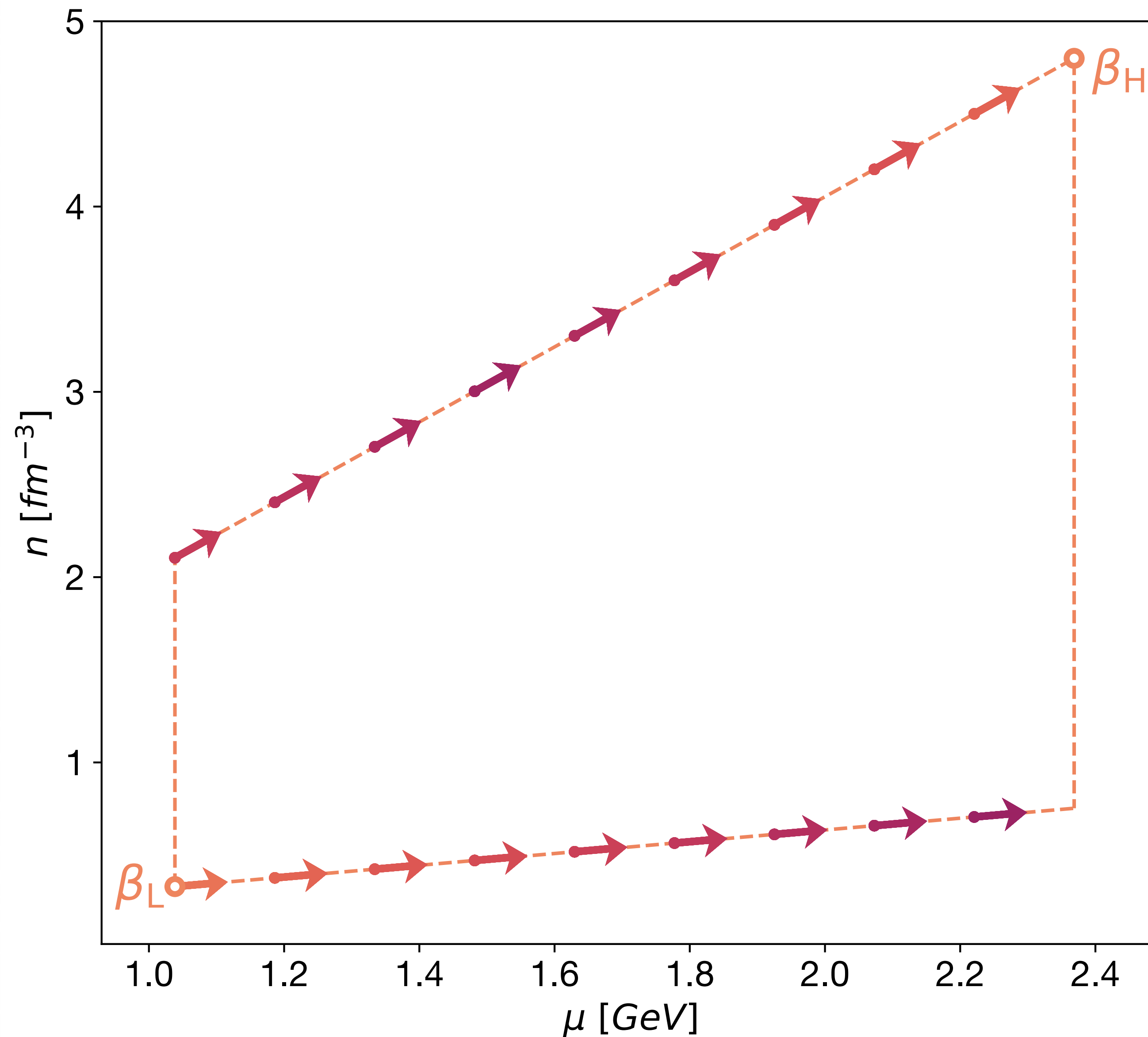
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causality

$$c_s^{-2} = \frac{\mu}{n} \frac{\partial n}{\partial \mu} \geq 1$$

self-similar [fractal] EoS



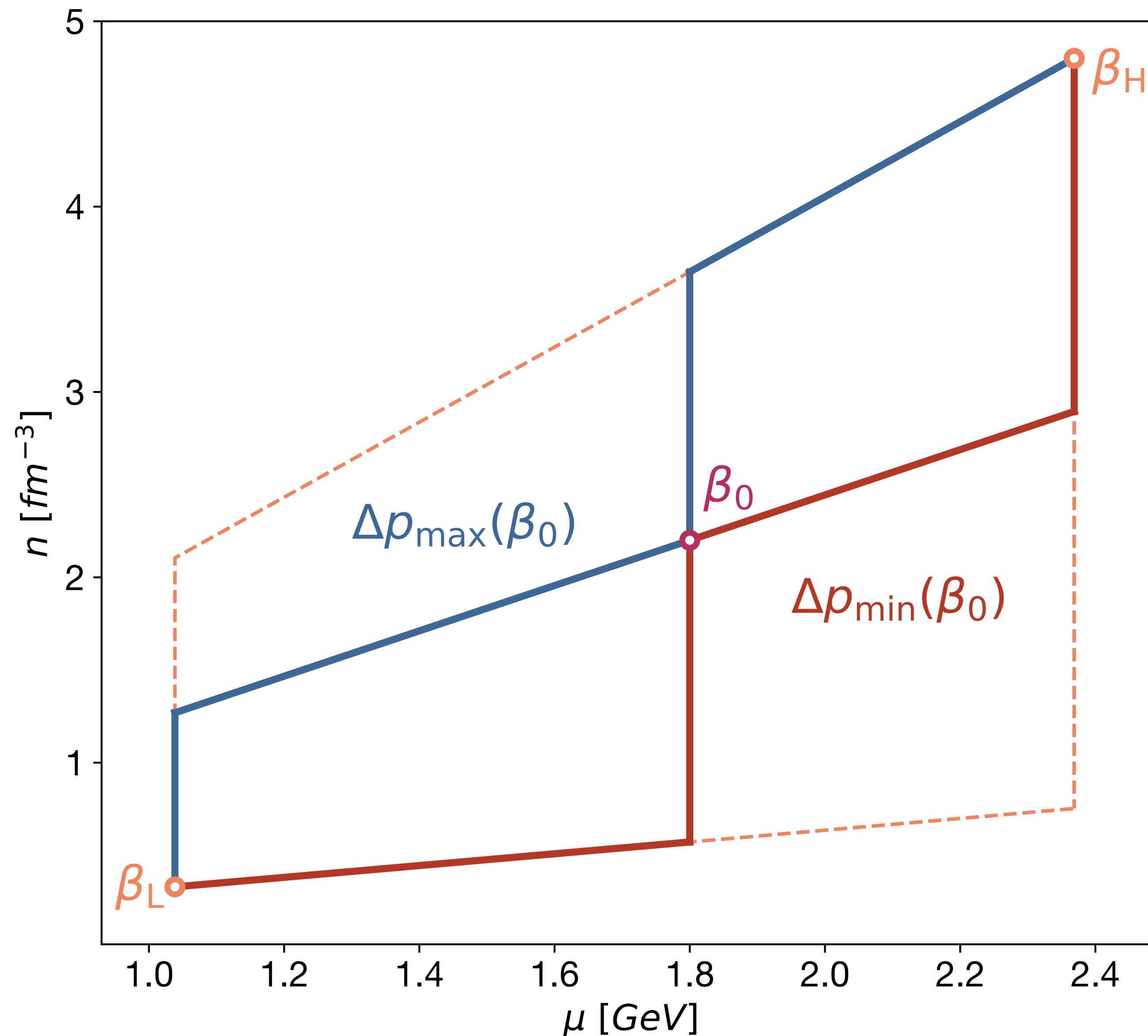
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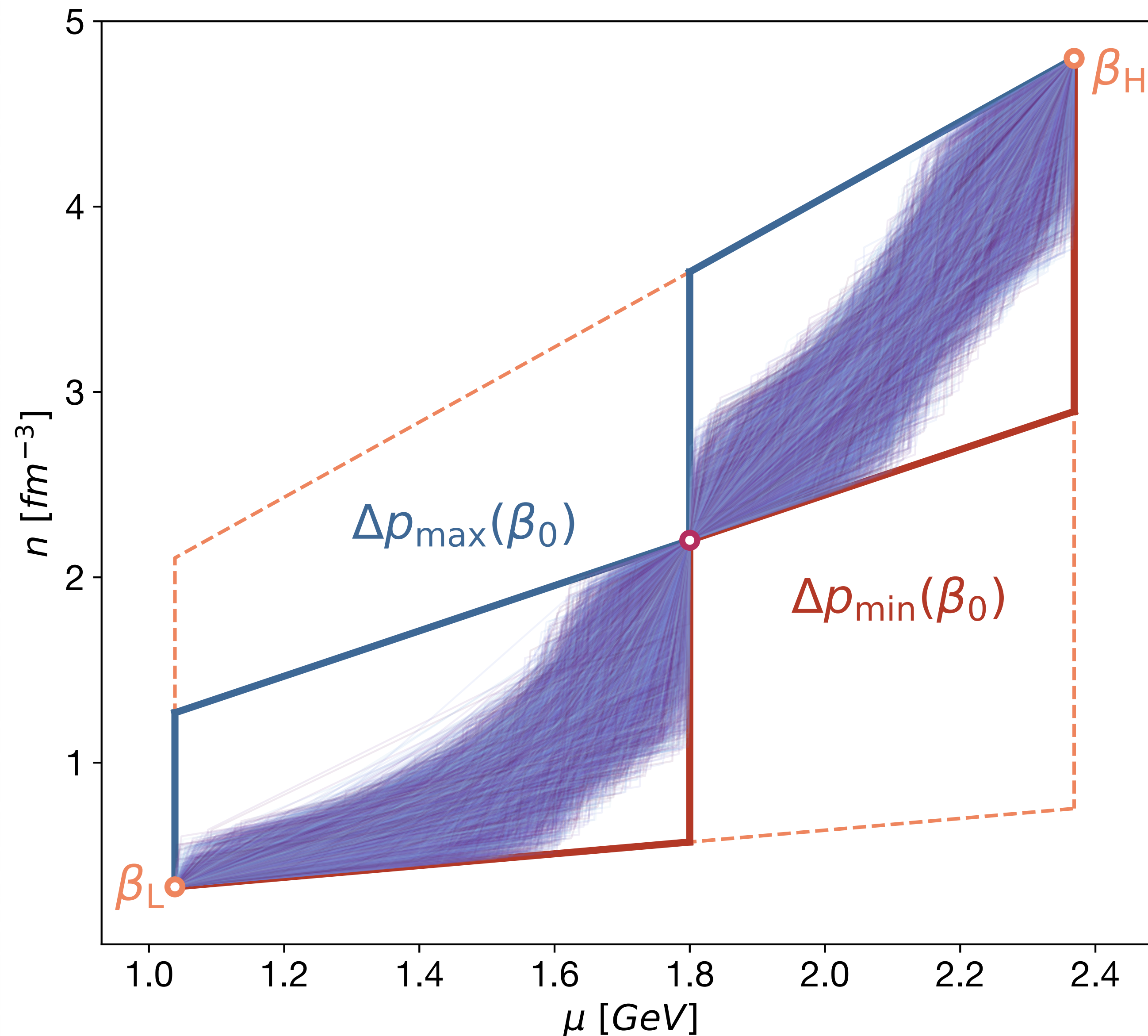
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$$c_s^{-2} = \frac{\mu}{n} \frac{\partial n}{\partial \mu} \geq 1$$

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$$\int_{\mu_L}^{\mu_H} n(\mu) d\mu = p_L - p_H = \Delta p$$

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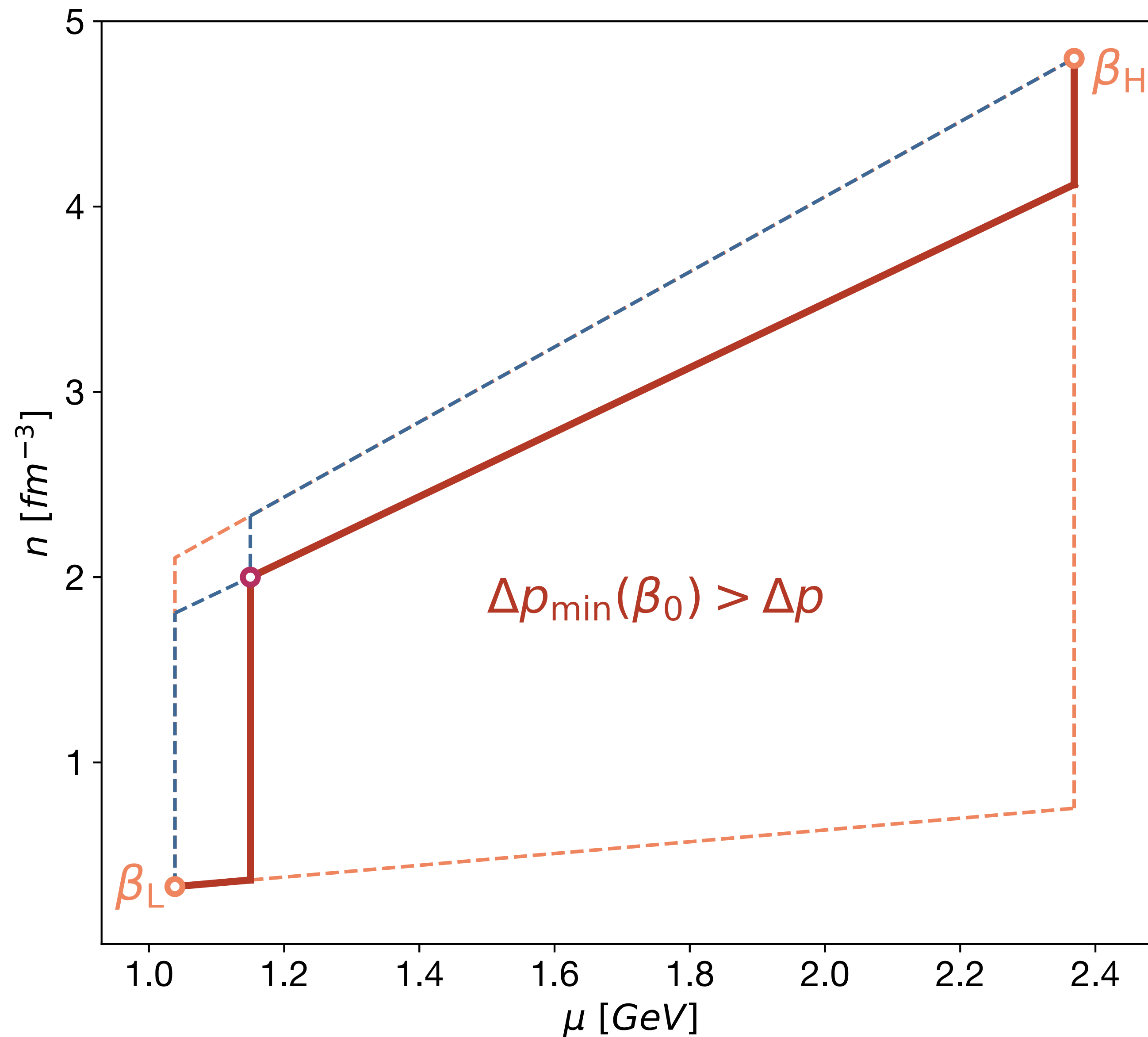
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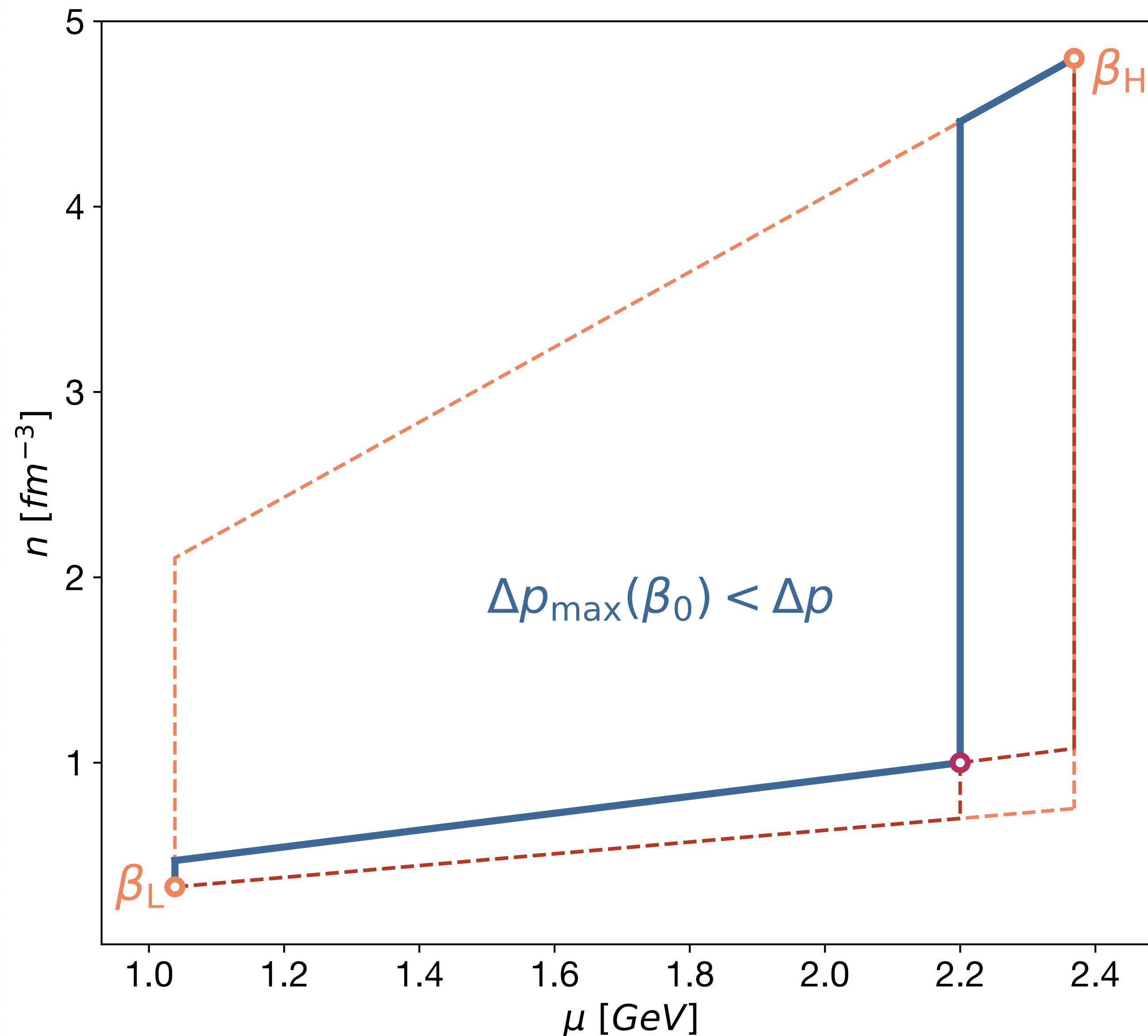
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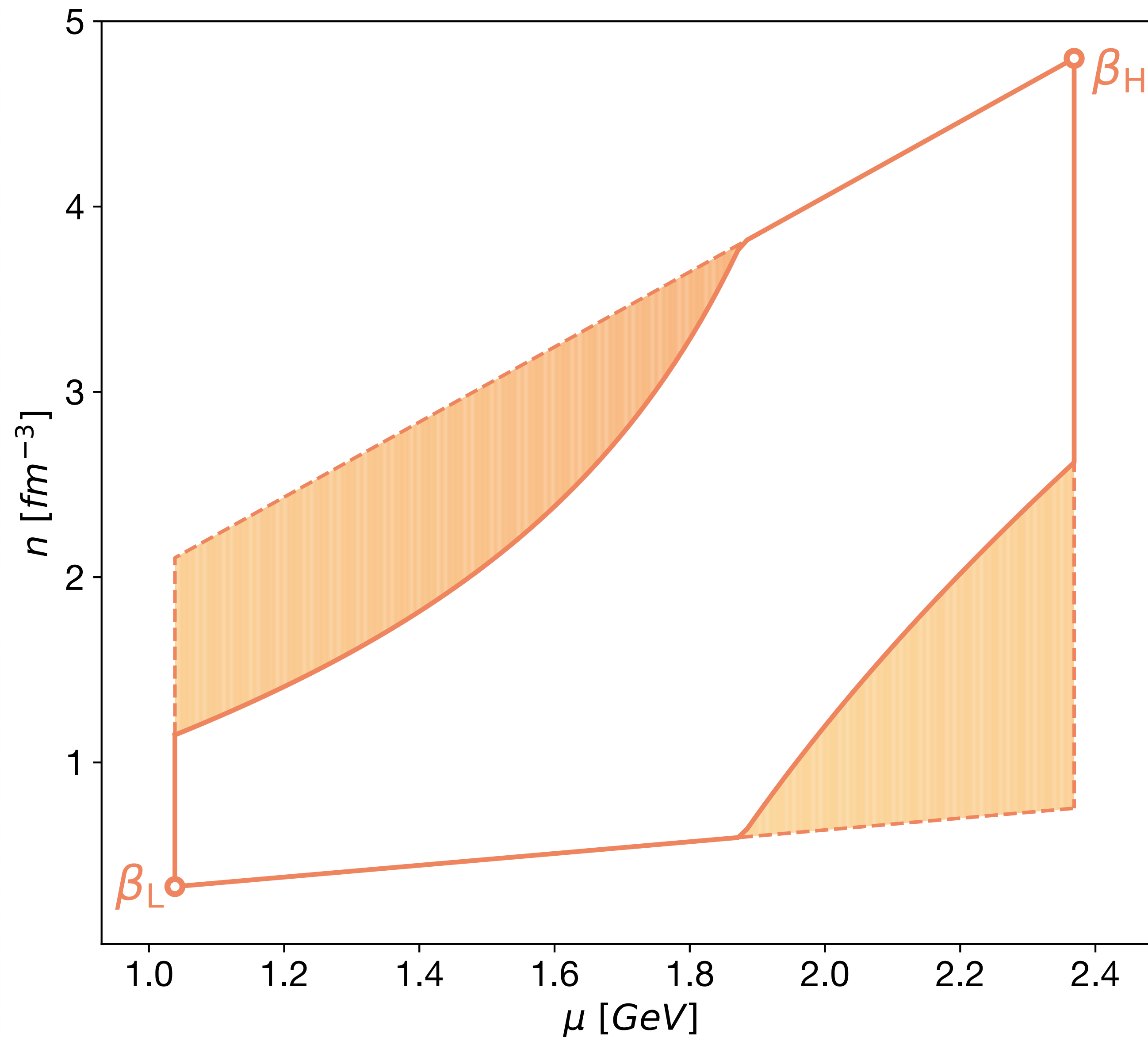
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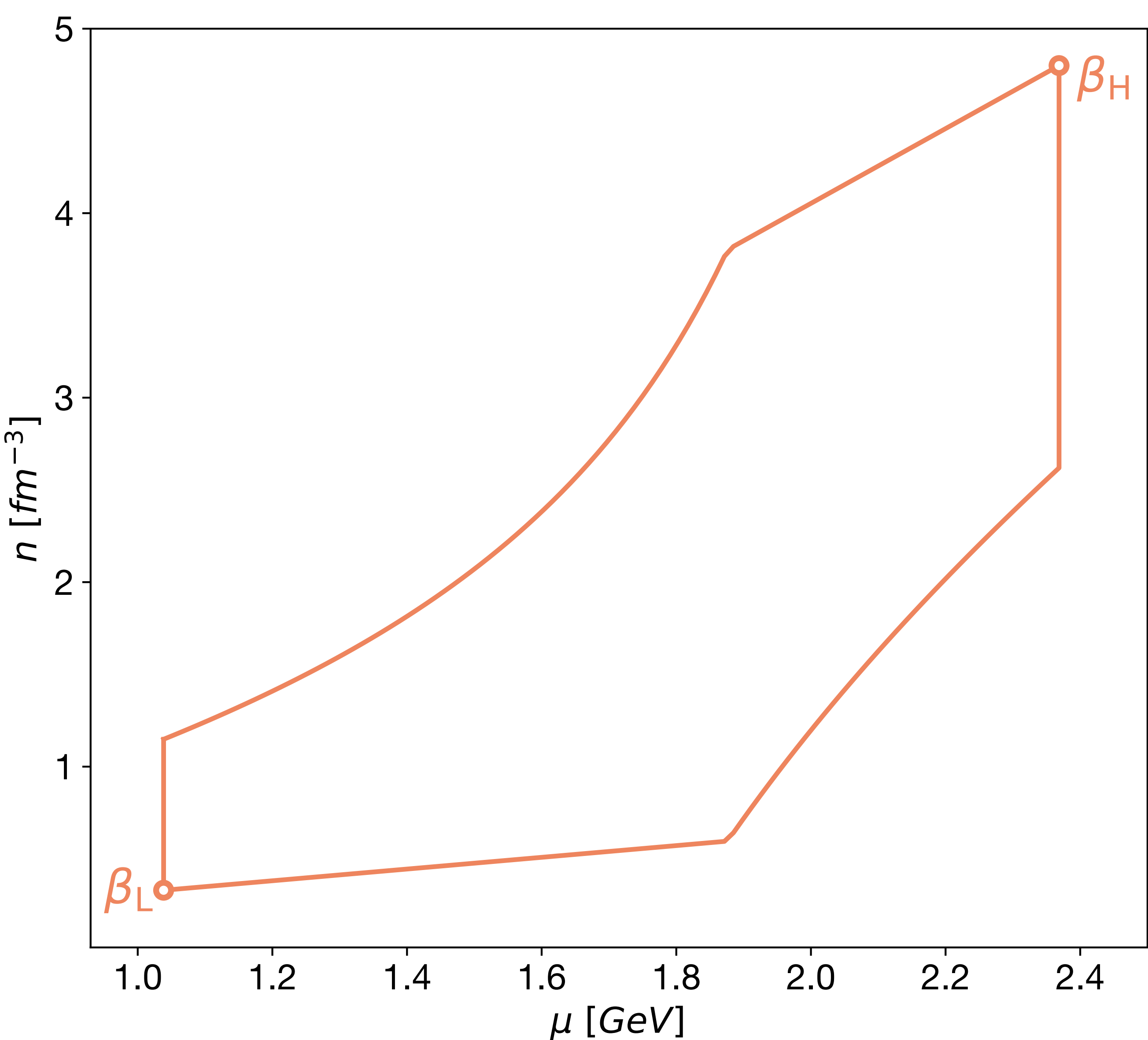
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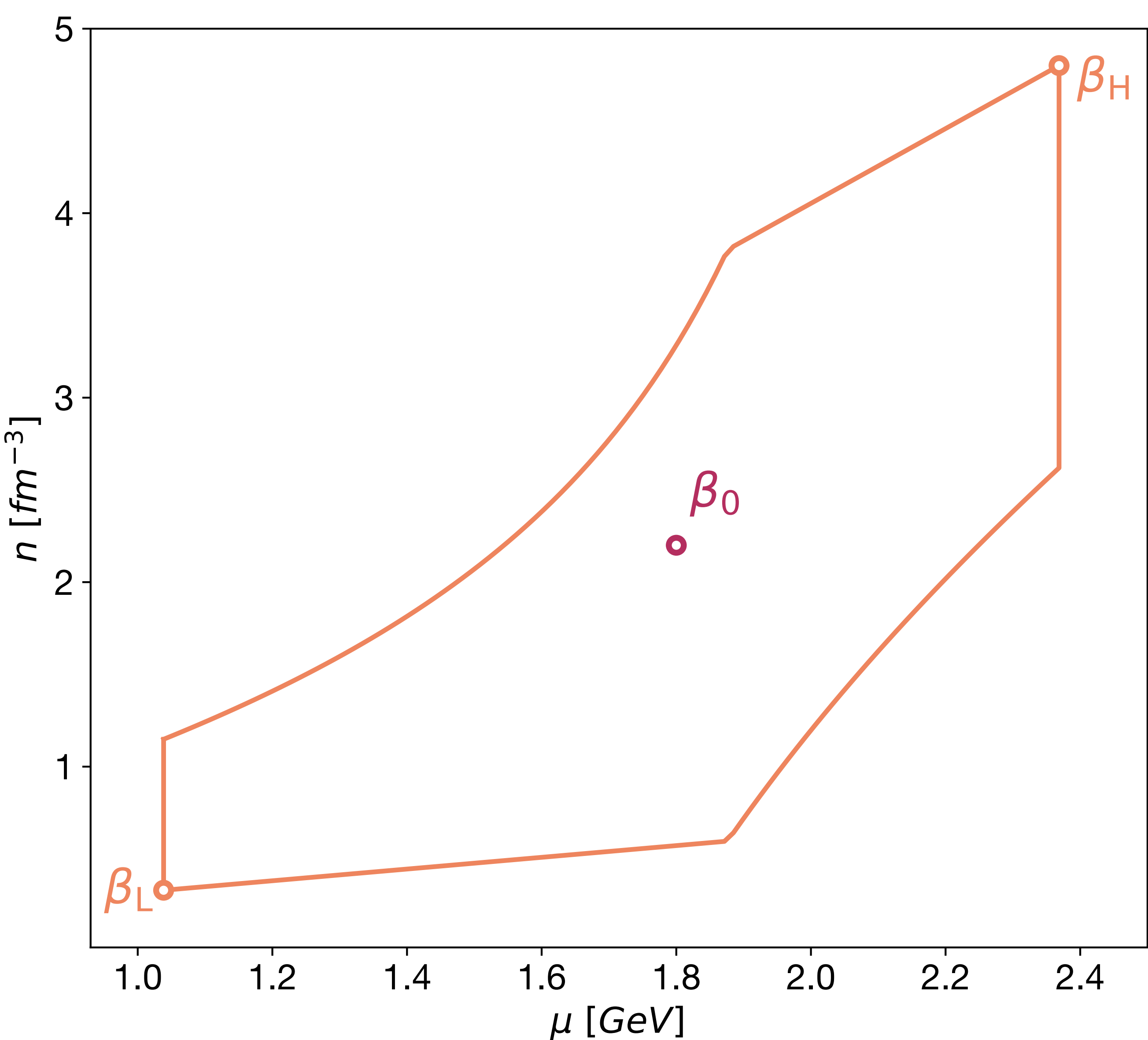
O.K., A. Kurkela. PRL 128 (2022) 20, 202701

self-similar [fractal] EoS

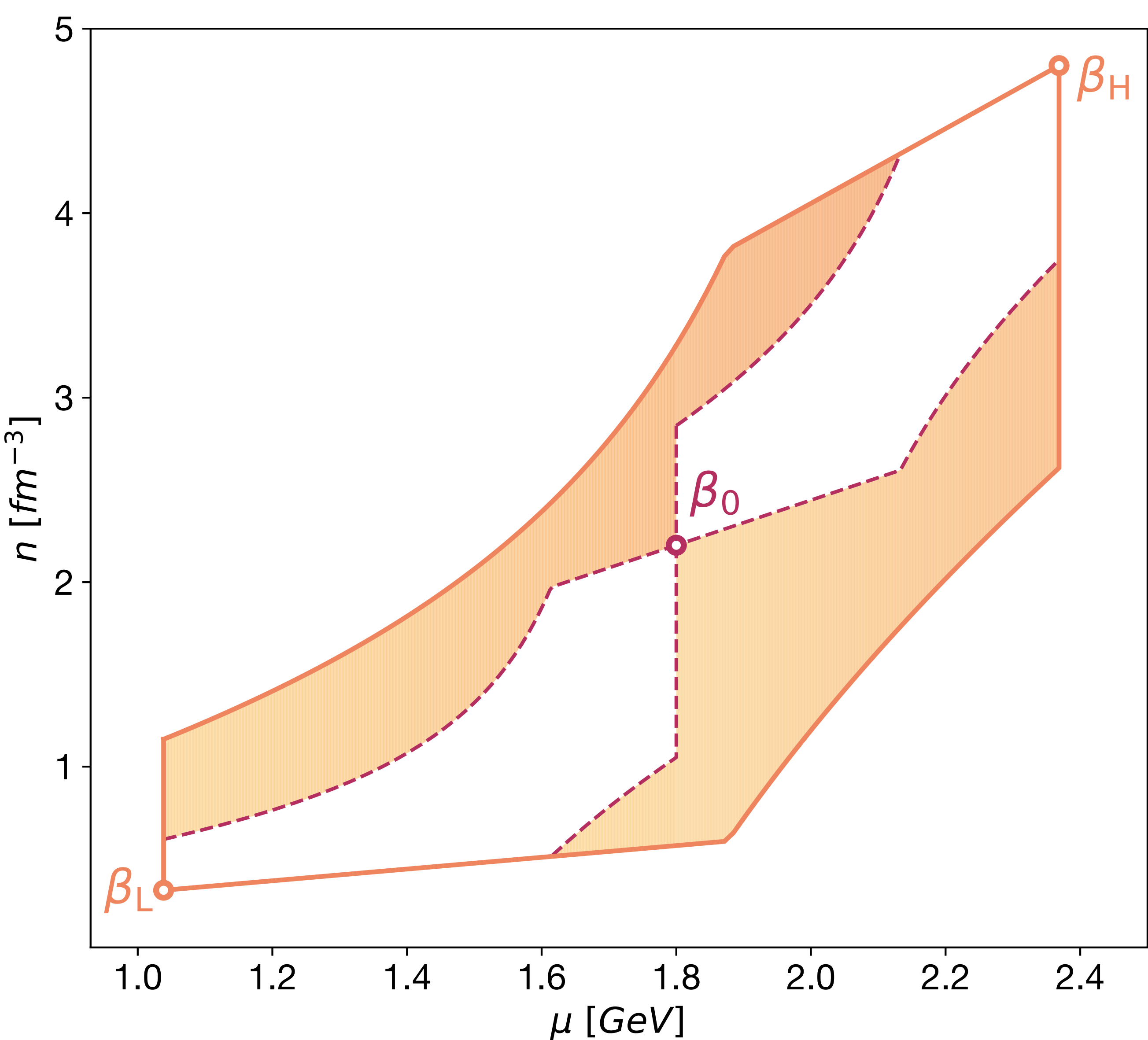


β_L, β_H are not special

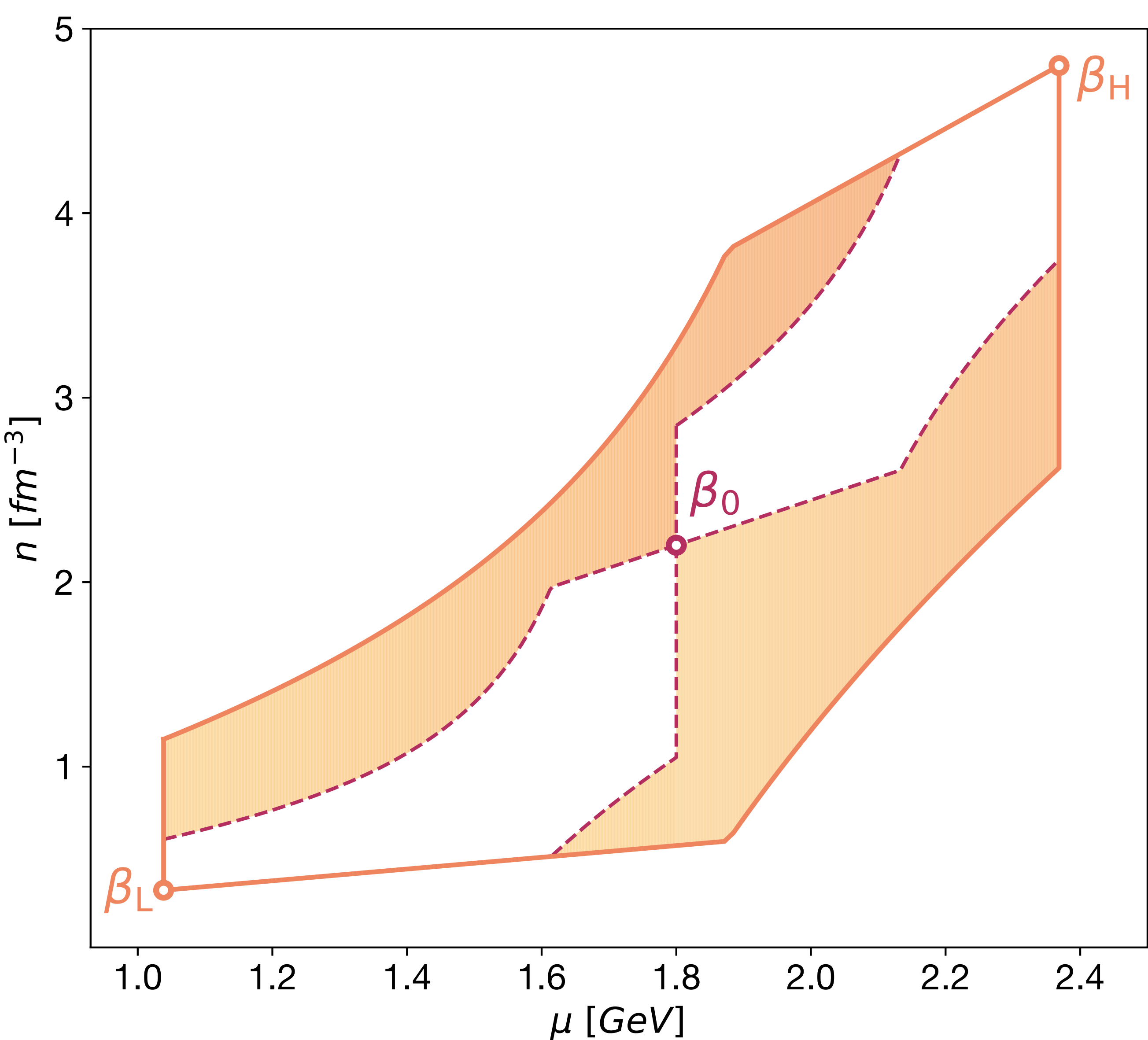
self-similar [fractal] EoS



self-similar [fractal] EoS

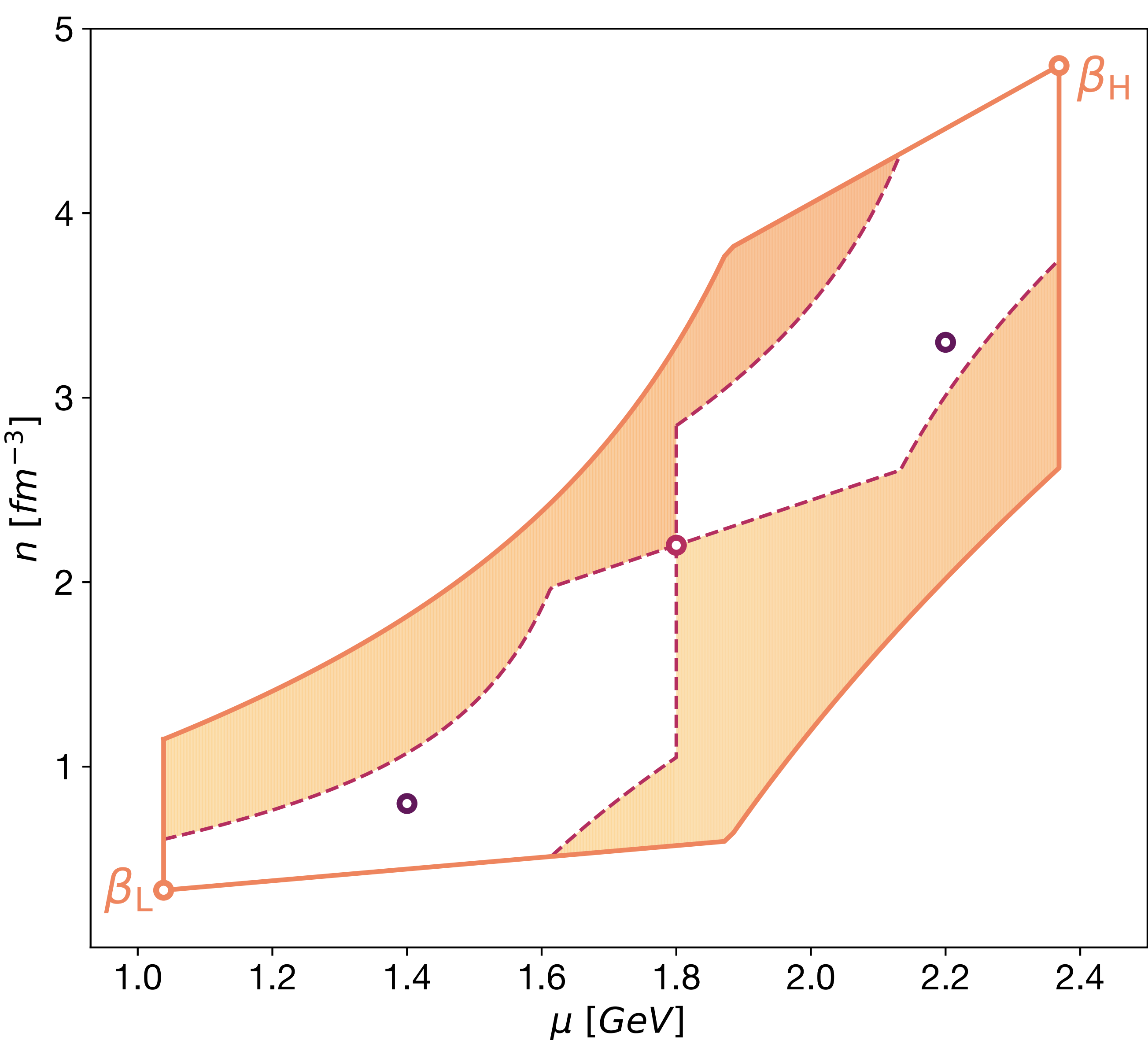


self-similar [fractal] EoS

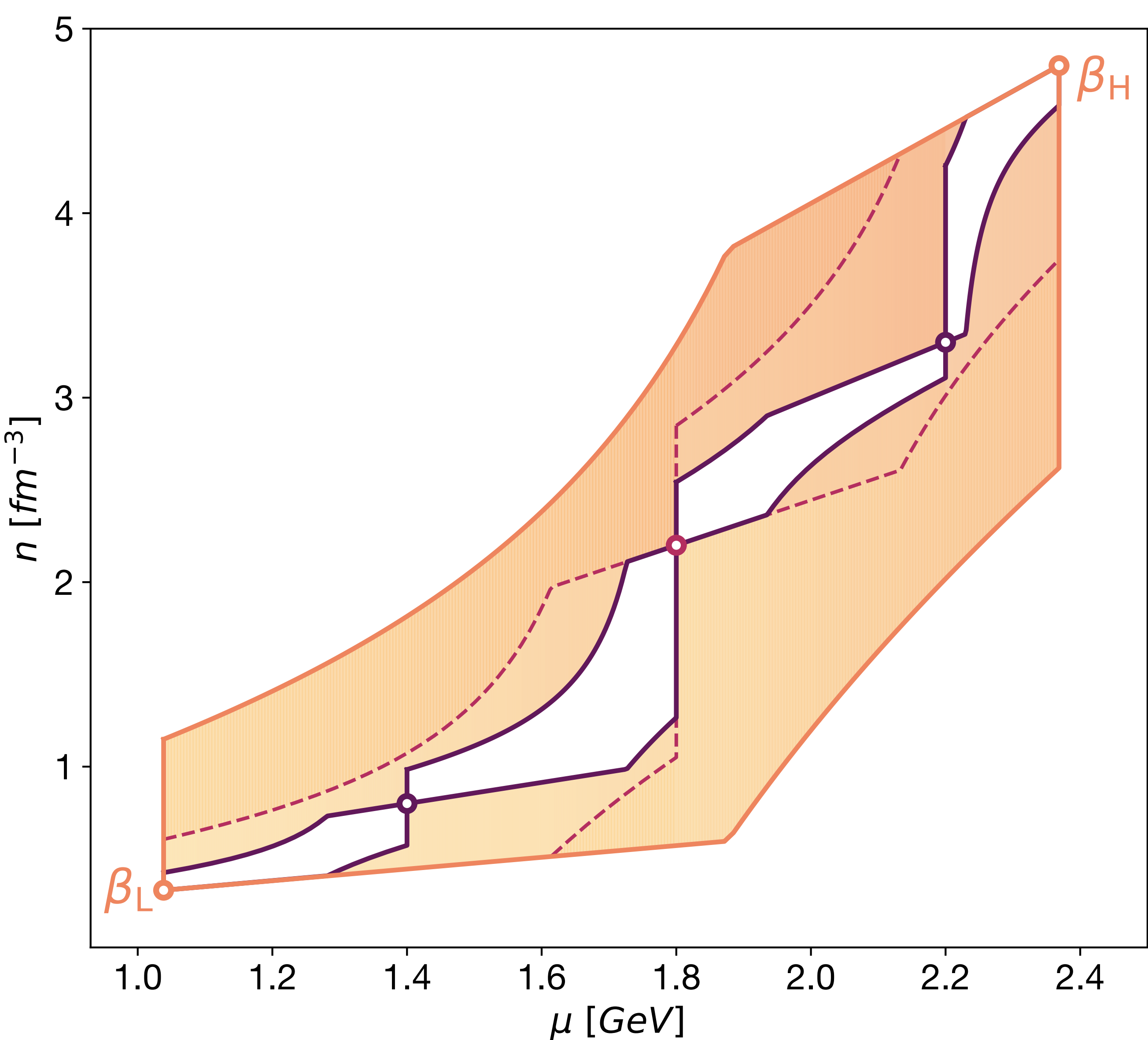


$\beta_L, \beta_0, \beta_H$ are not special

self-similar [fractal] EoS

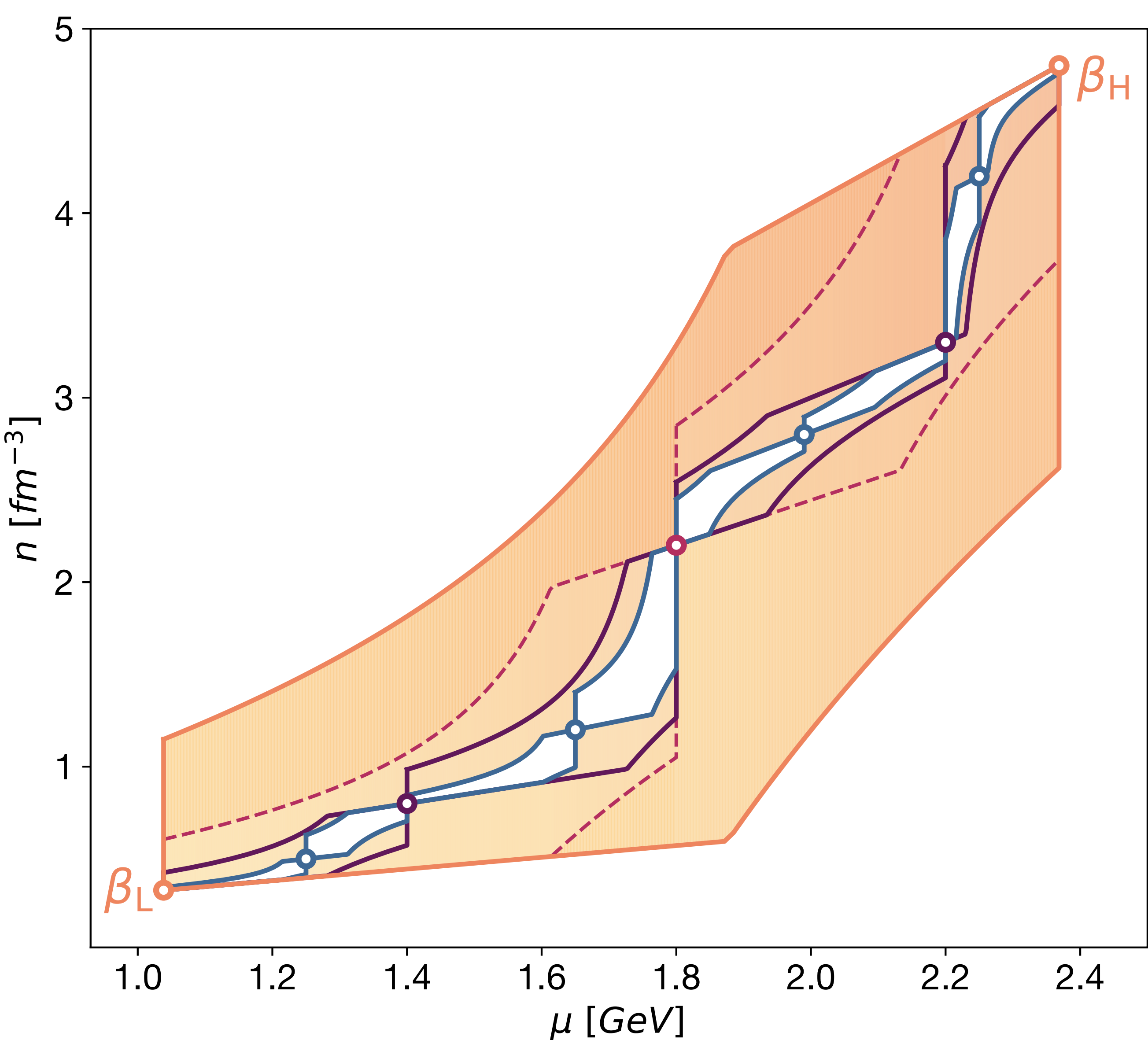


self-similar [fractal] EoS



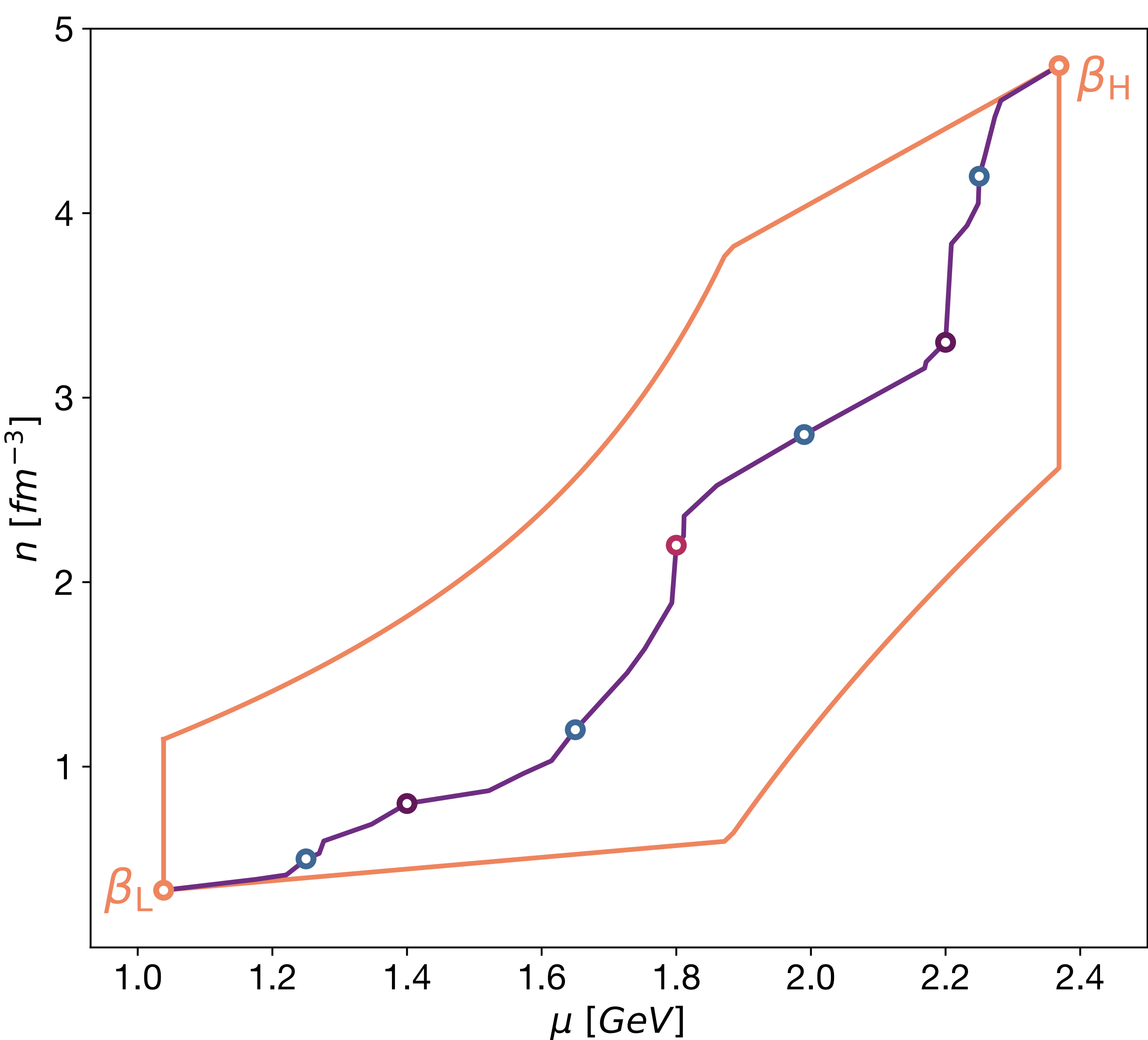
more

self-similar [fractal] EoS

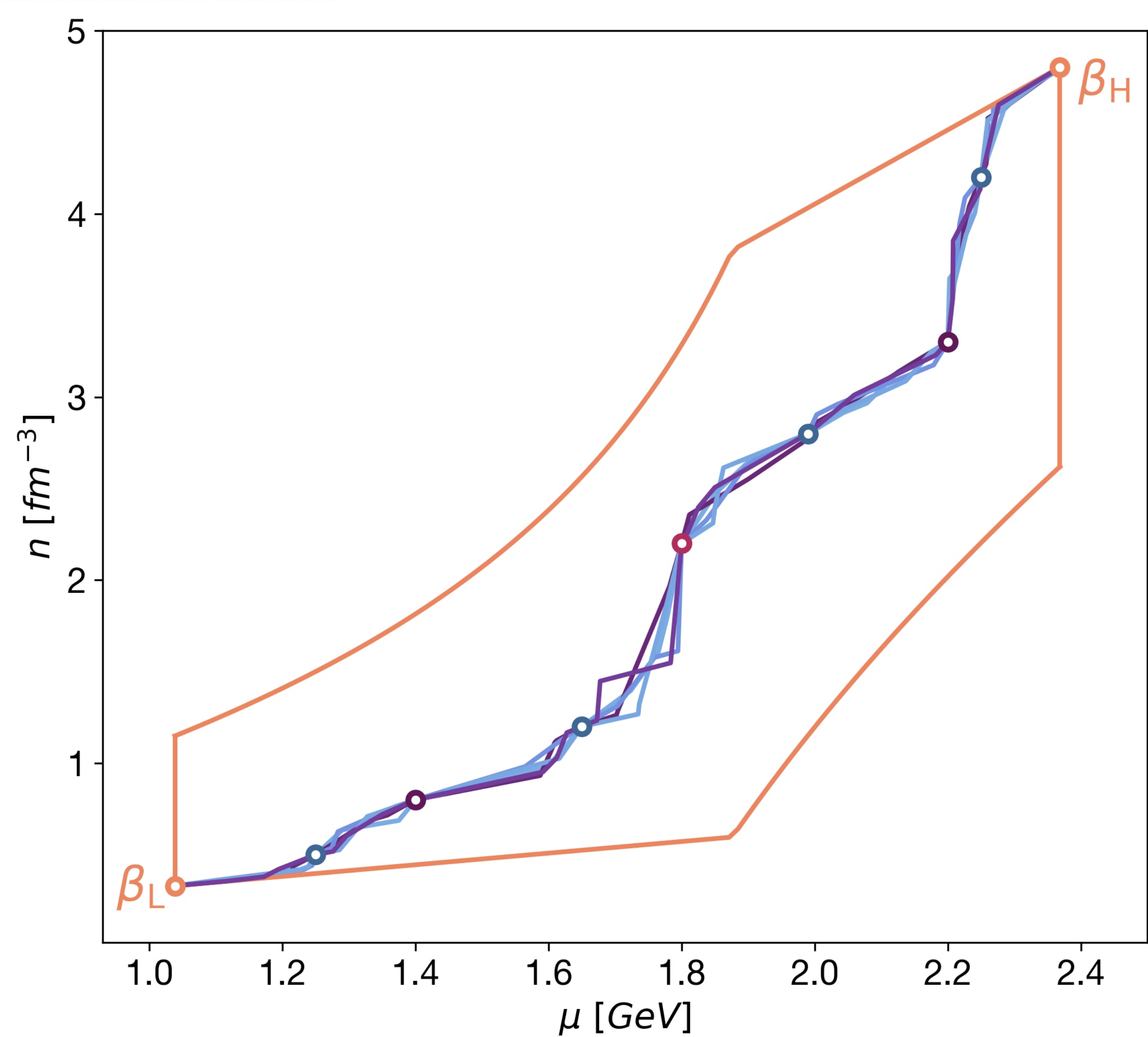


MORE

self-similar [fractal] EoS

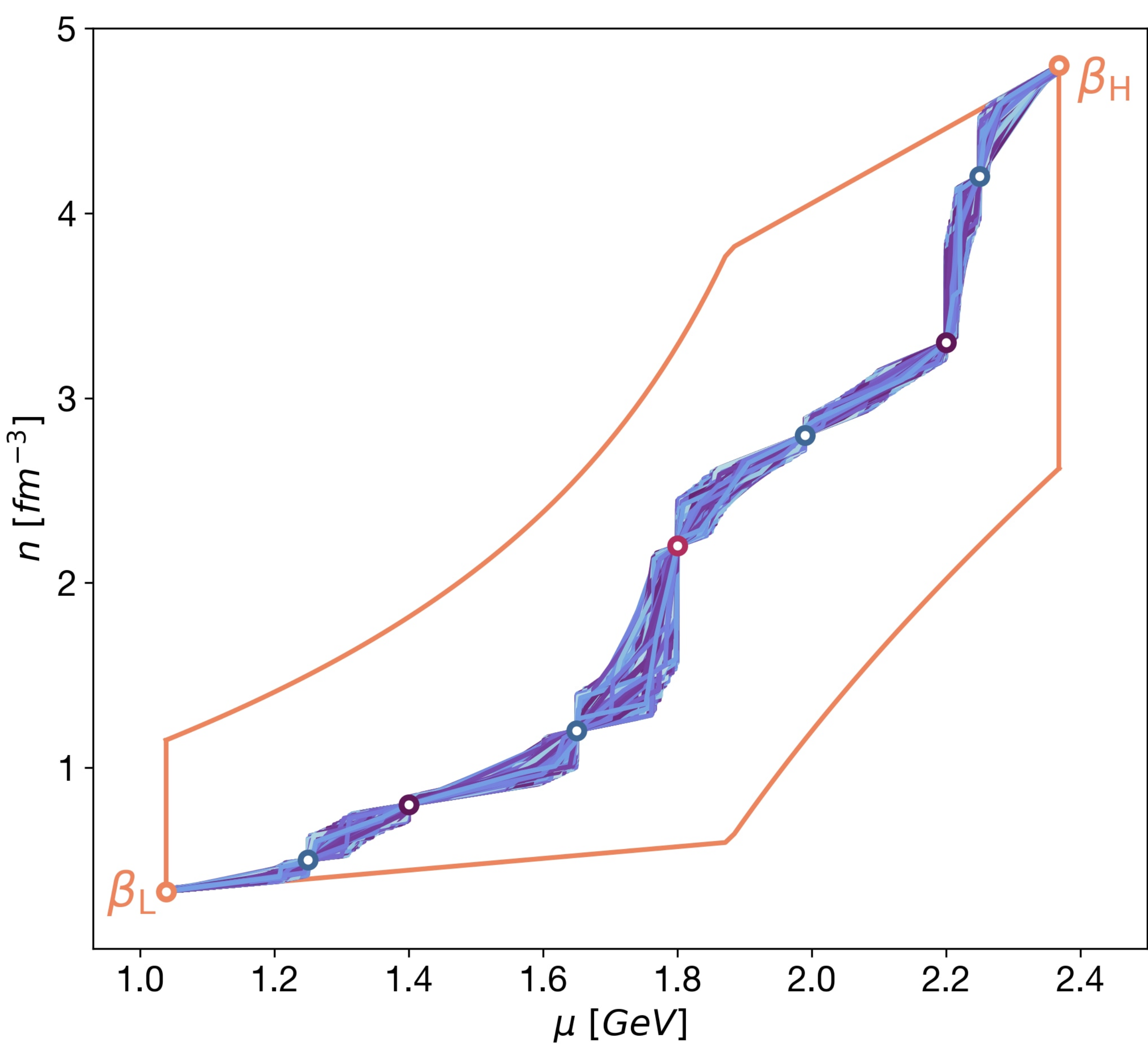


self-similar [fractal] EoS



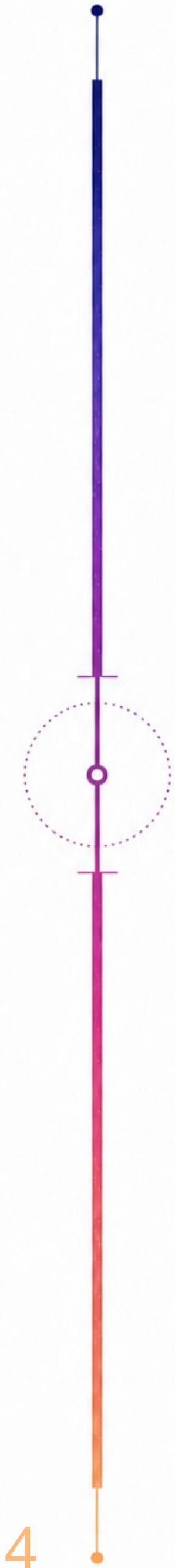
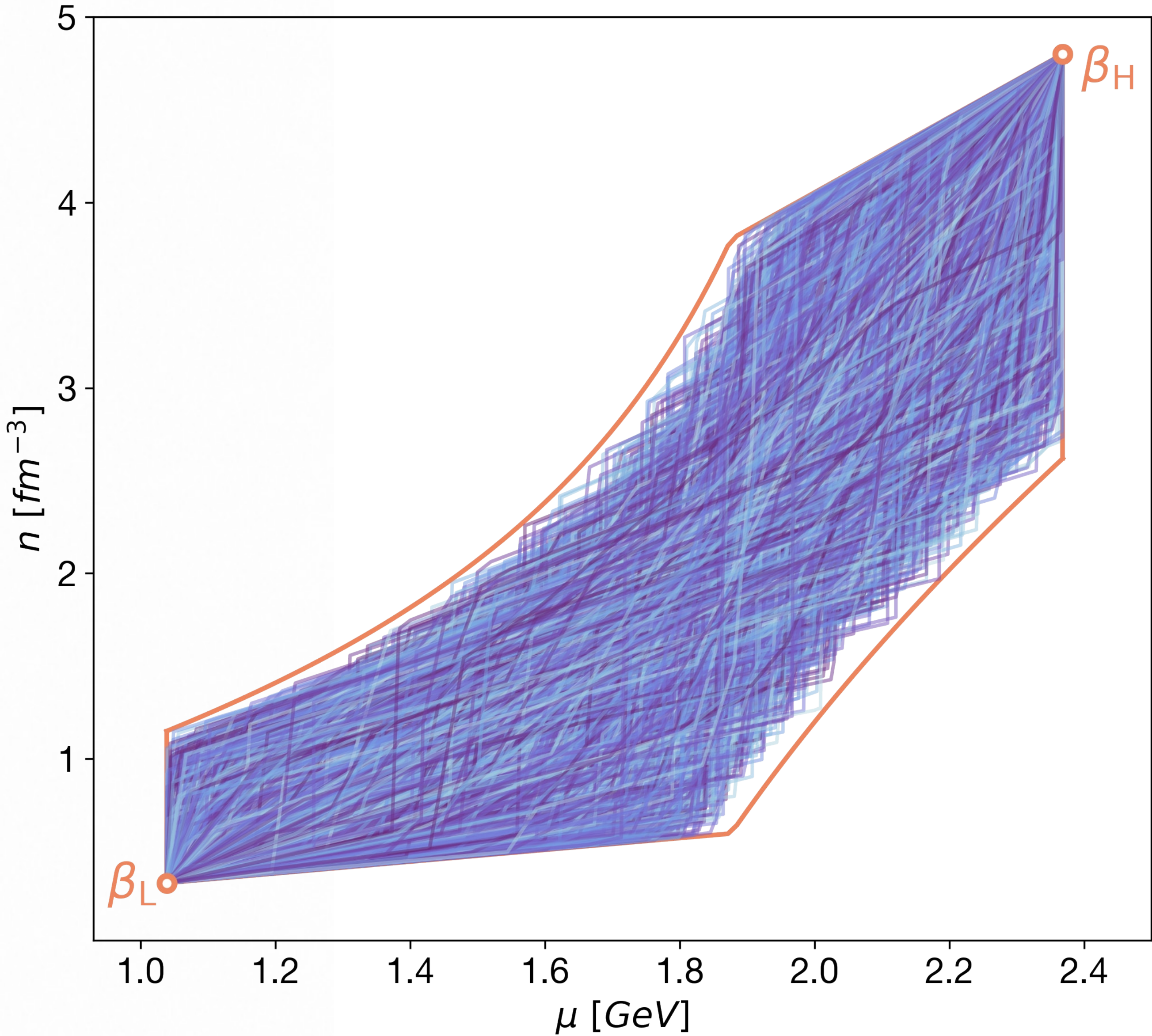
more

self-similar [fractal] EoS

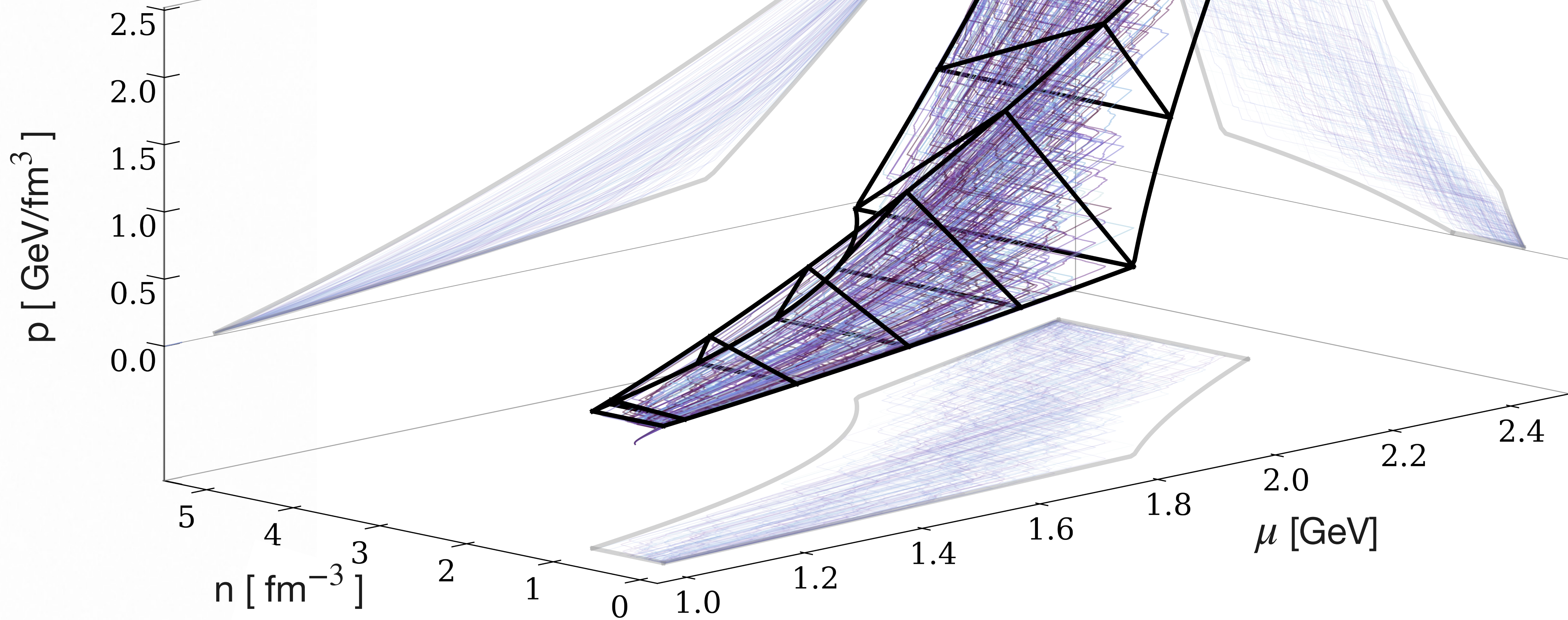


MORE

self-similar [fractal] EoS



self-similar [fractal] EoS



volume is uniformly sampled

introducing local Gaussian correlation

the diffusion equation

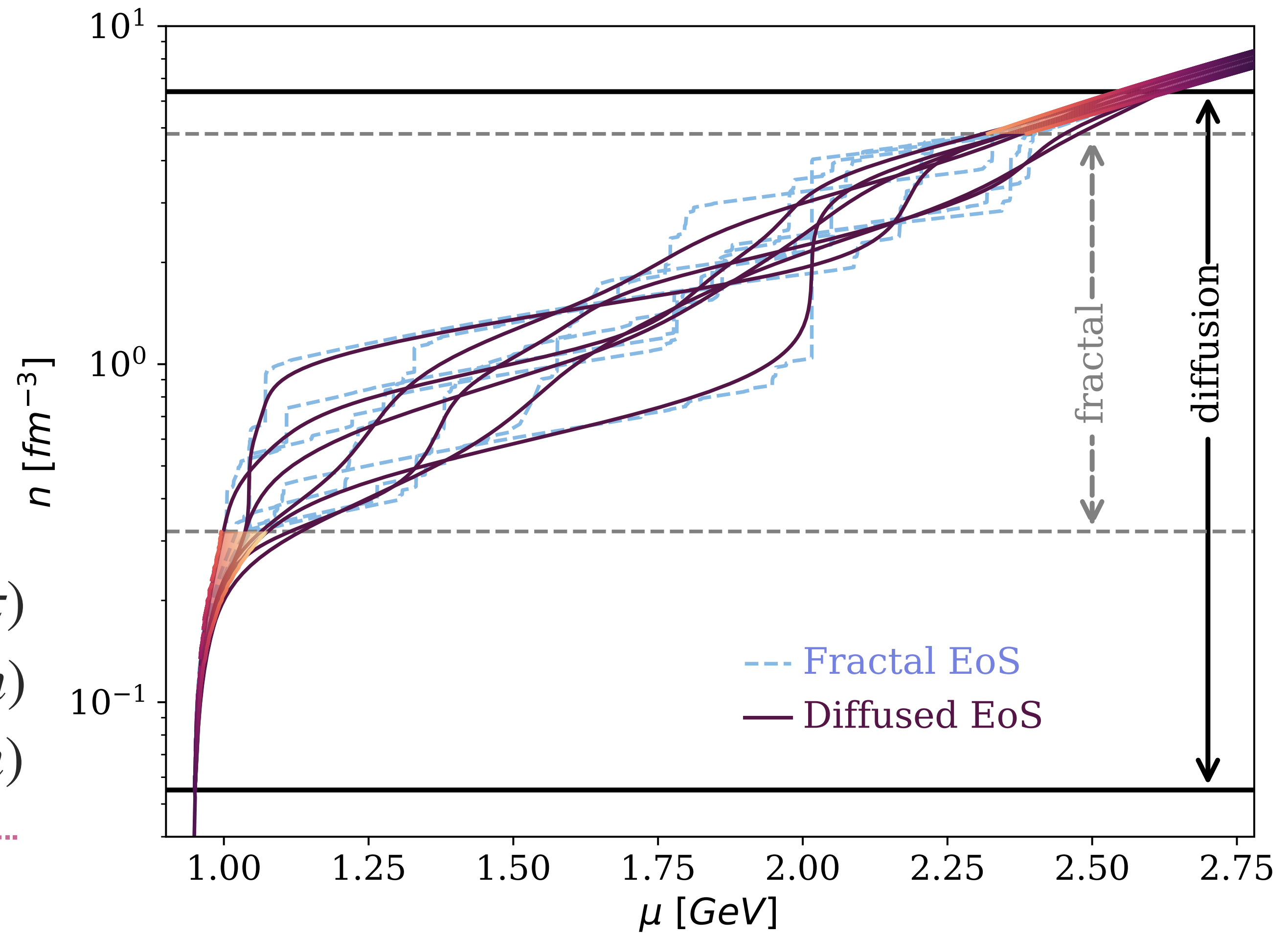
$$\partial_\tau \mu(n, \tau) = \partial_n [D(n) \partial_n \mu(n, \tau)]$$

unphysical time flow $\mu(n) \rightarrow \mu(n, \tau)$

density-dependent coefficient $D(n)$

initial condition $\mu(n, 0) = \mu(n)$

Dirichlet boundary conditions



introducing local Gaussian correlation

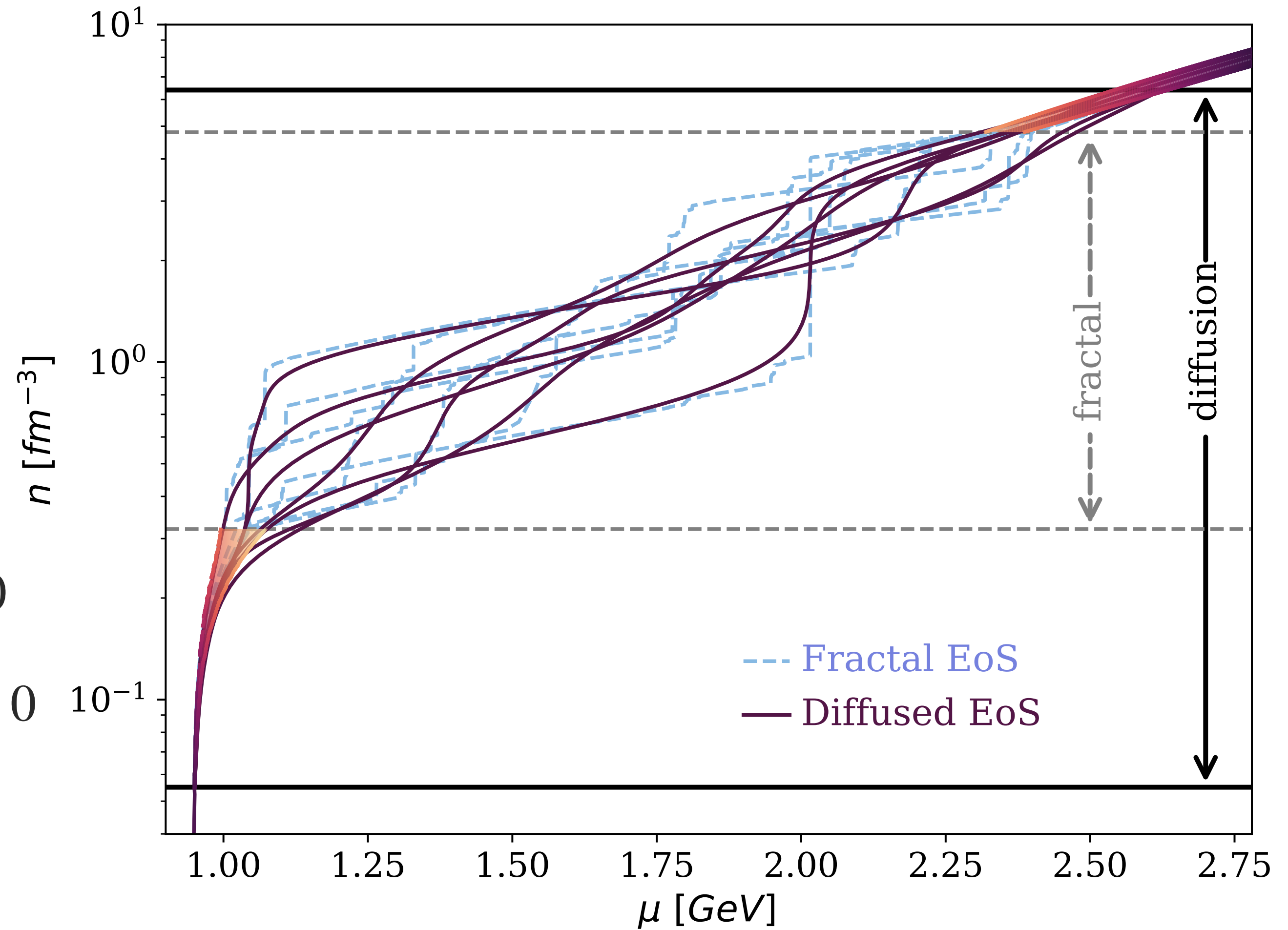
the diffusion equation

$$\partial_\tau \mu(n, \tau) = \partial_n [D(n) \partial_n \mu(n, \tau)]$$

stability $\partial_n \mu(n, 0) > 0 \quad \& \quad D(n) > 0$

causality $c_s^2(n, 0) \leq 1 \quad \& \quad D'' - \frac{D'}{n} \leq 0$

consistency $\varepsilon' - \varepsilon = \int_n^{n'} \mu(n) dn$

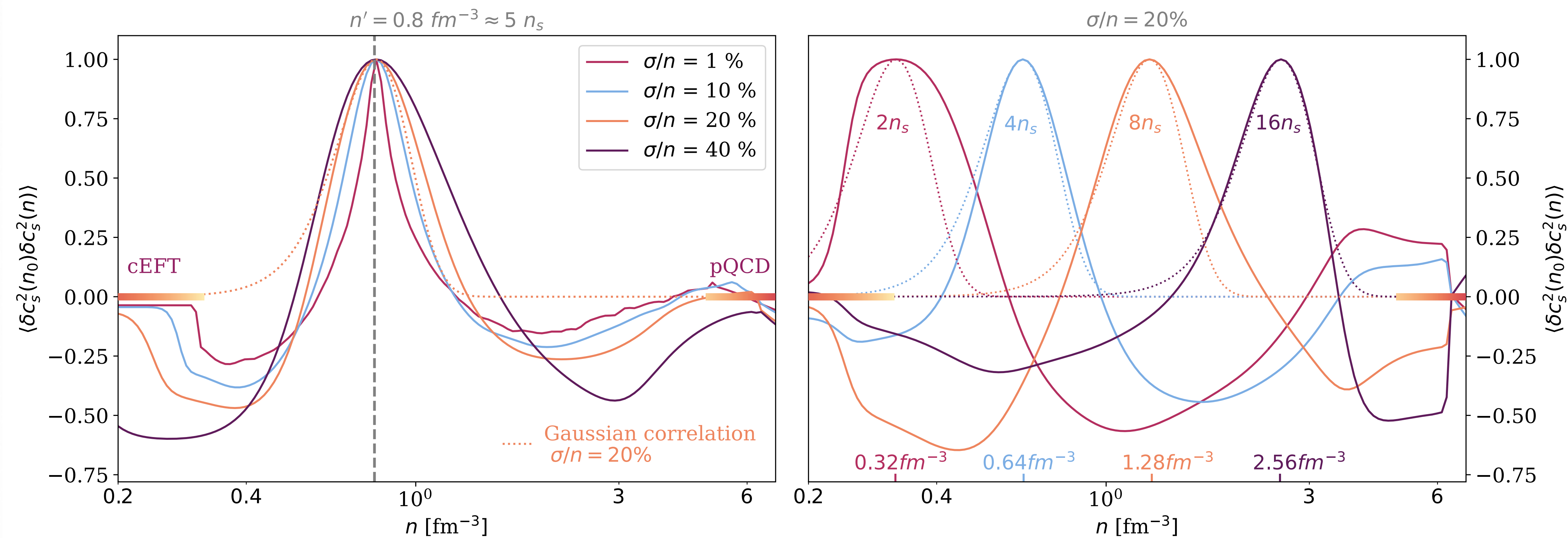


introducing local Gaussian correlation

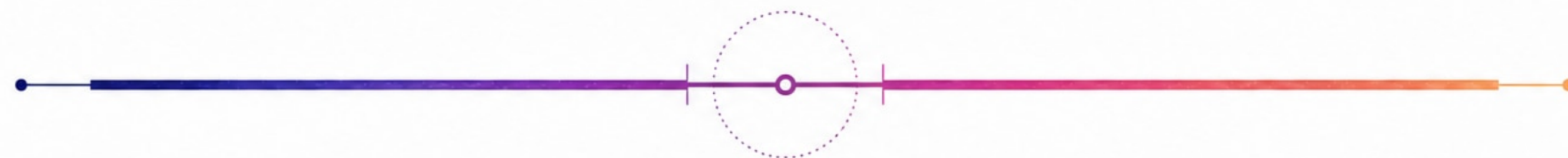
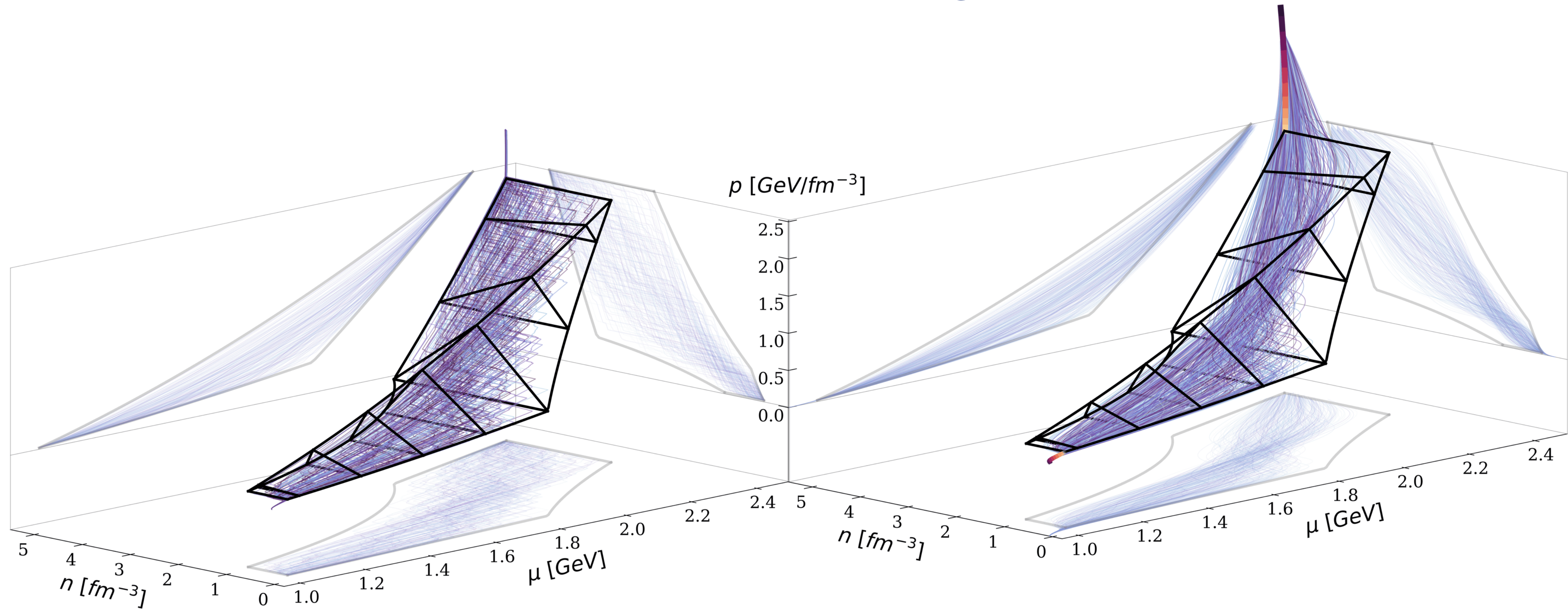
correlation length $\sigma = \sqrt{4D(n)\tau}$

logarithmically constant $\sigma/n = c$

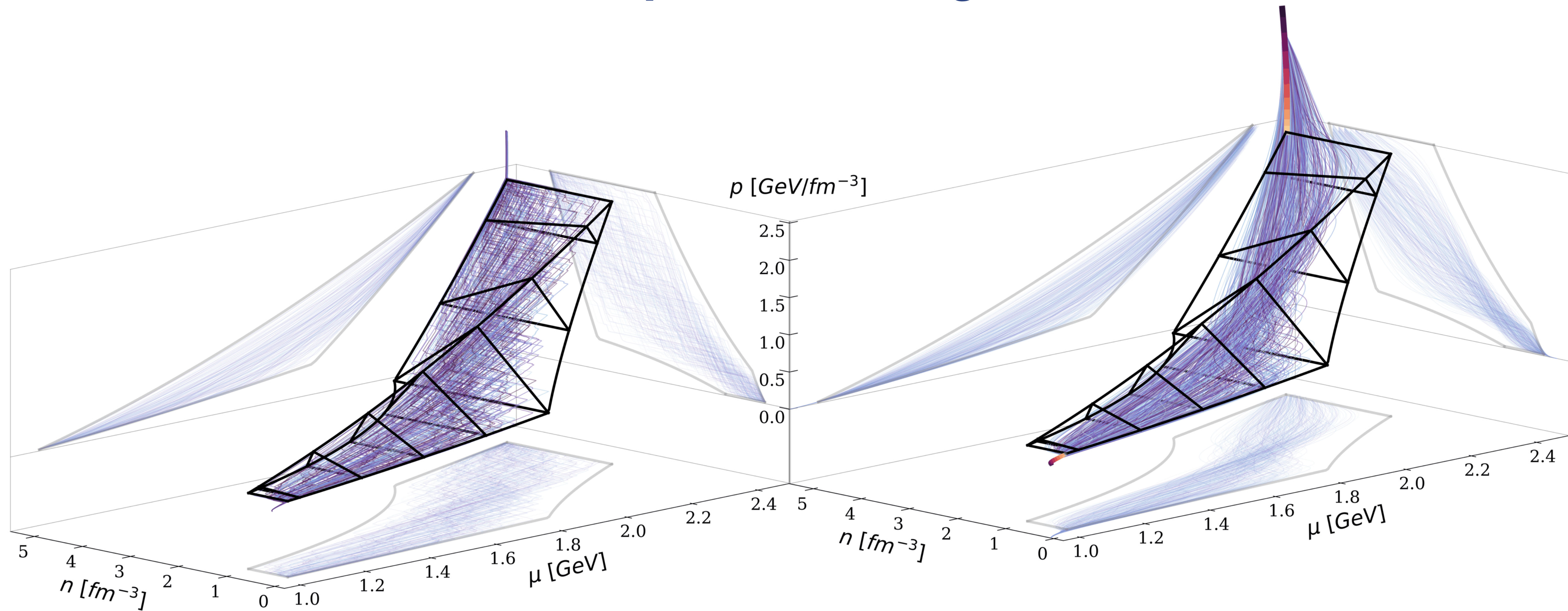
choose $D(n)\tau = n^2c^2/4$



constrained Gaussian-process bridge

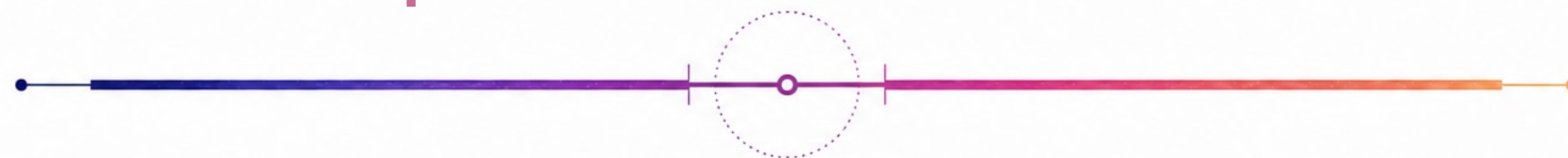


constrained Gaussian-process bridge

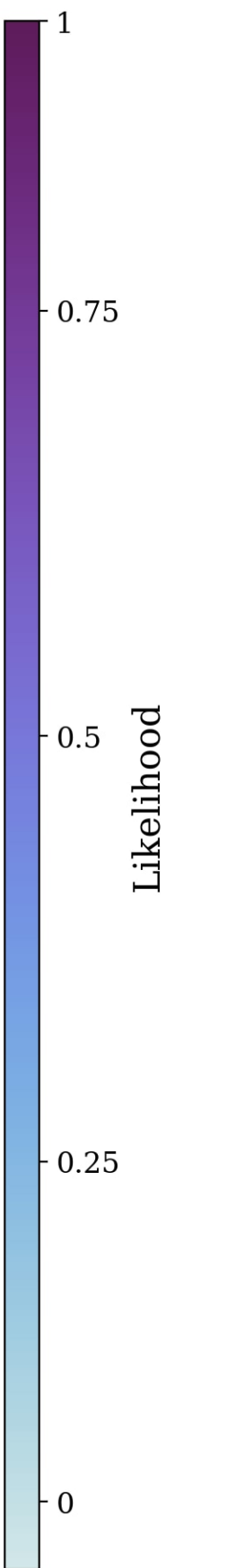
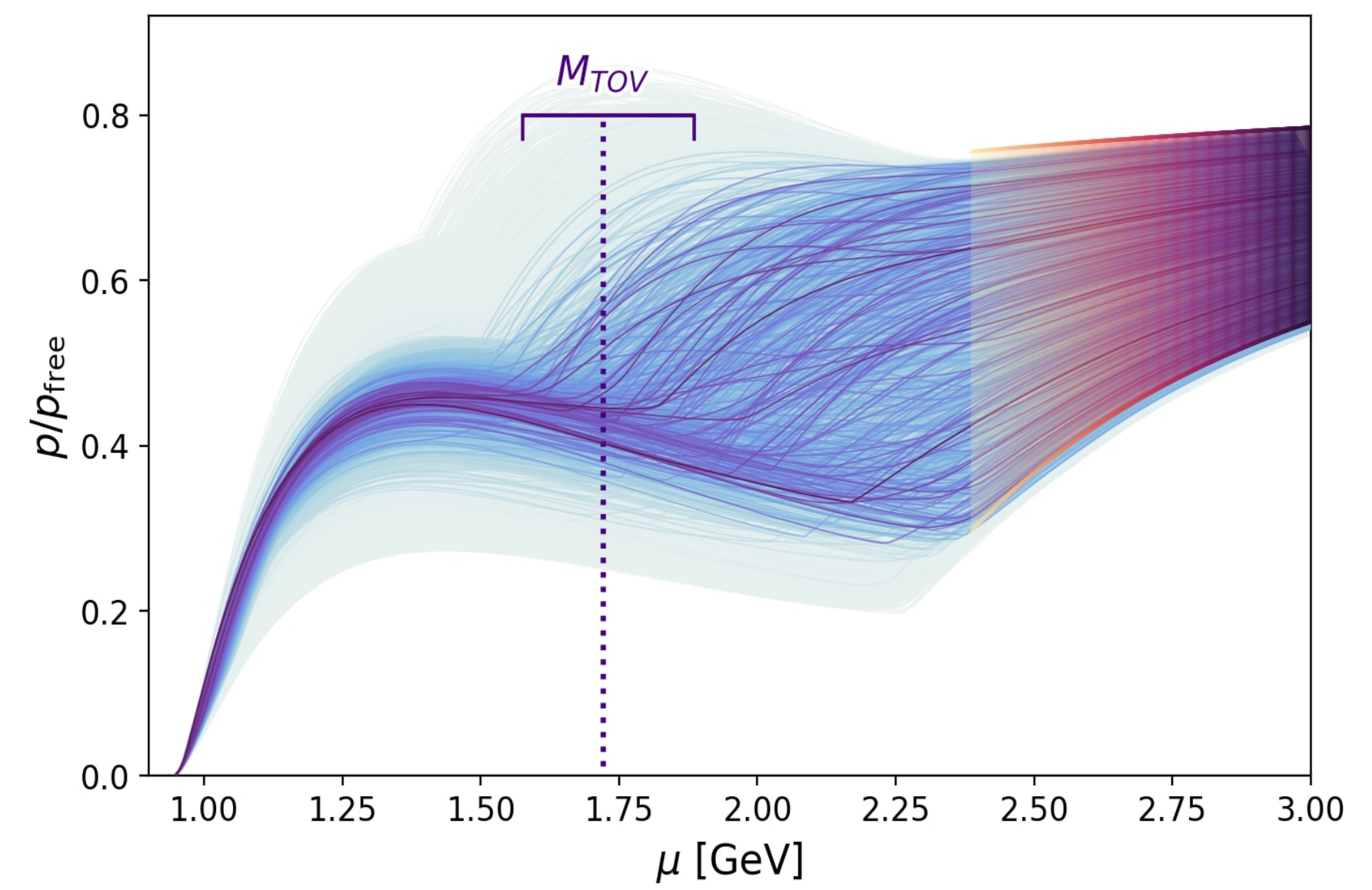
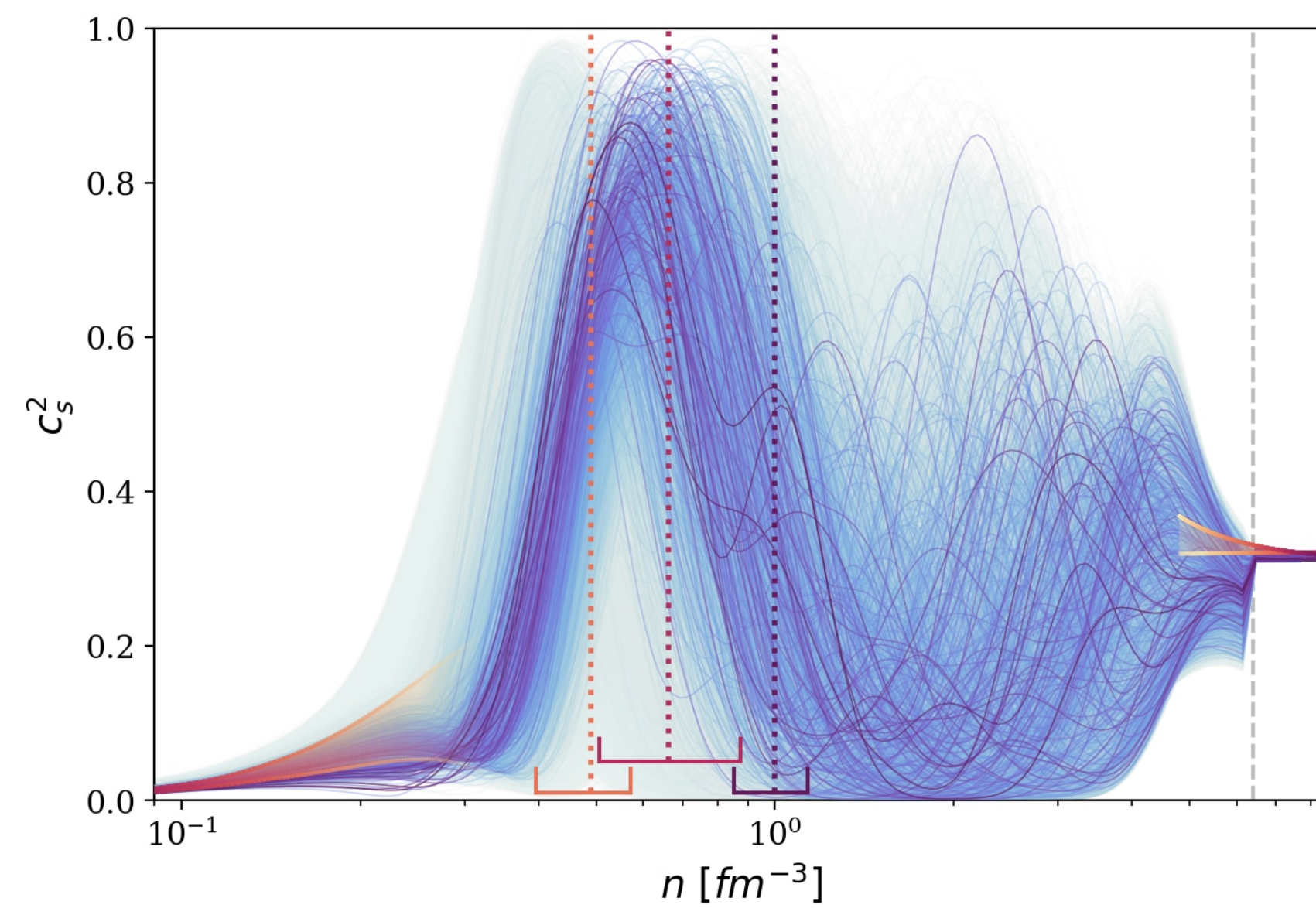
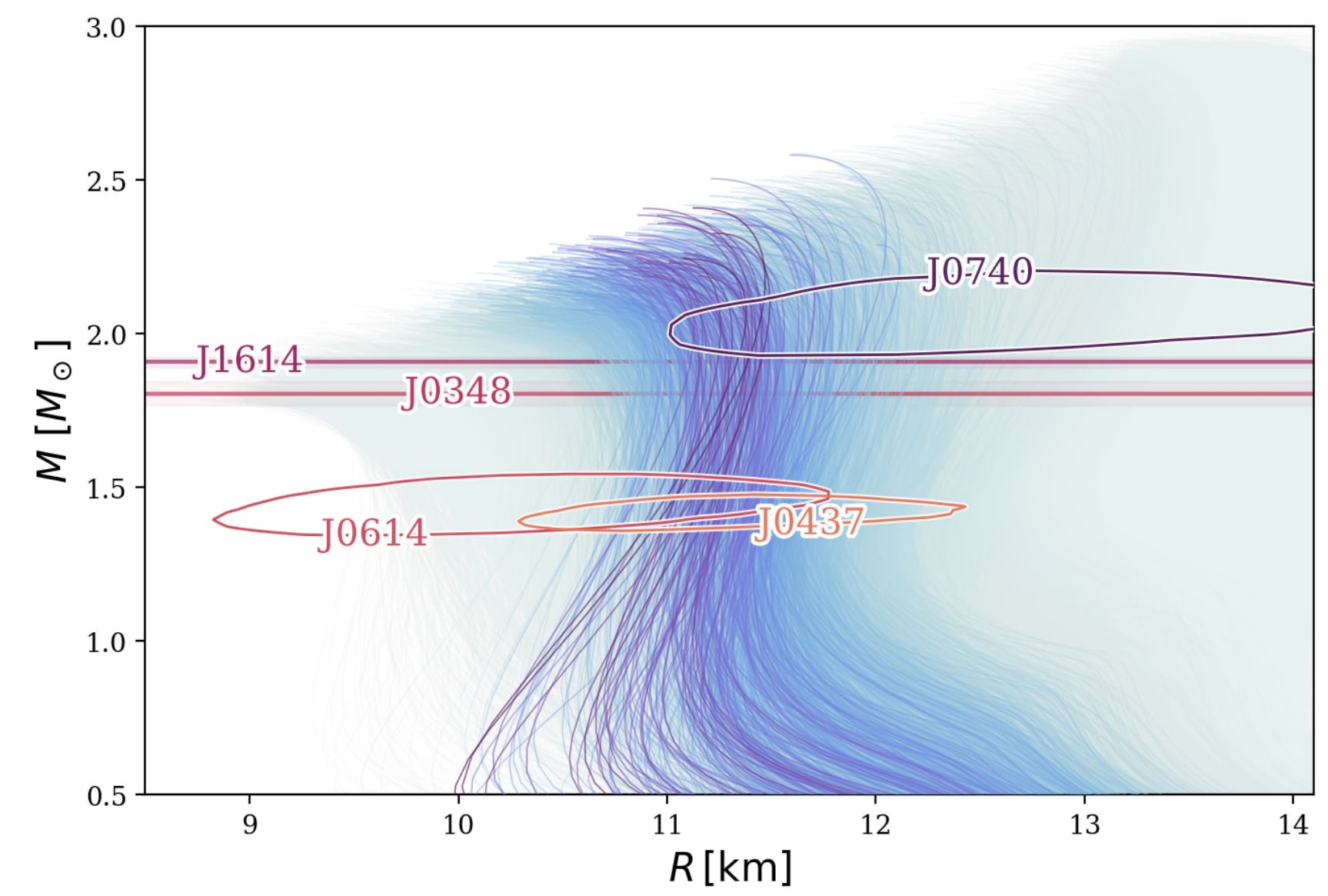
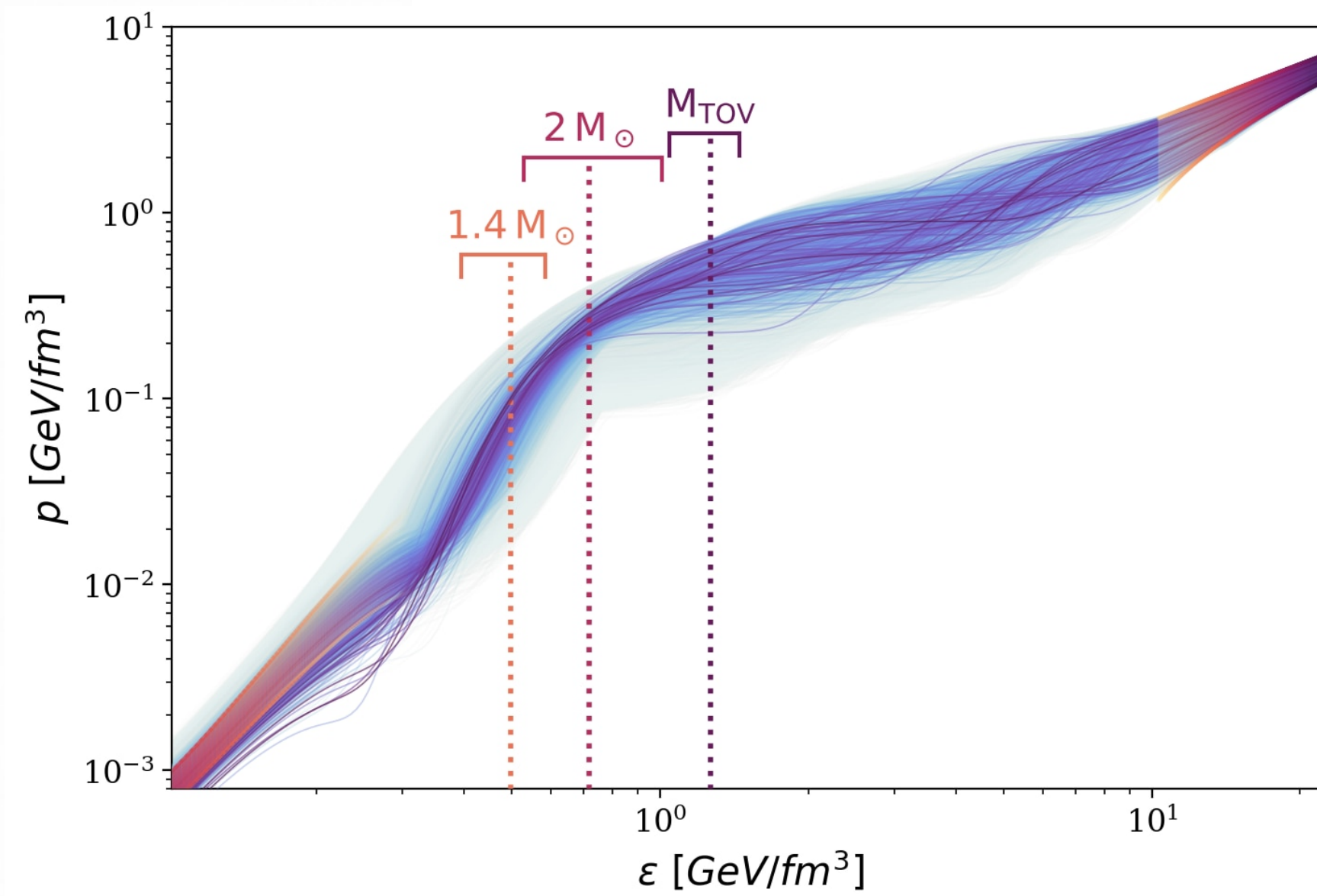


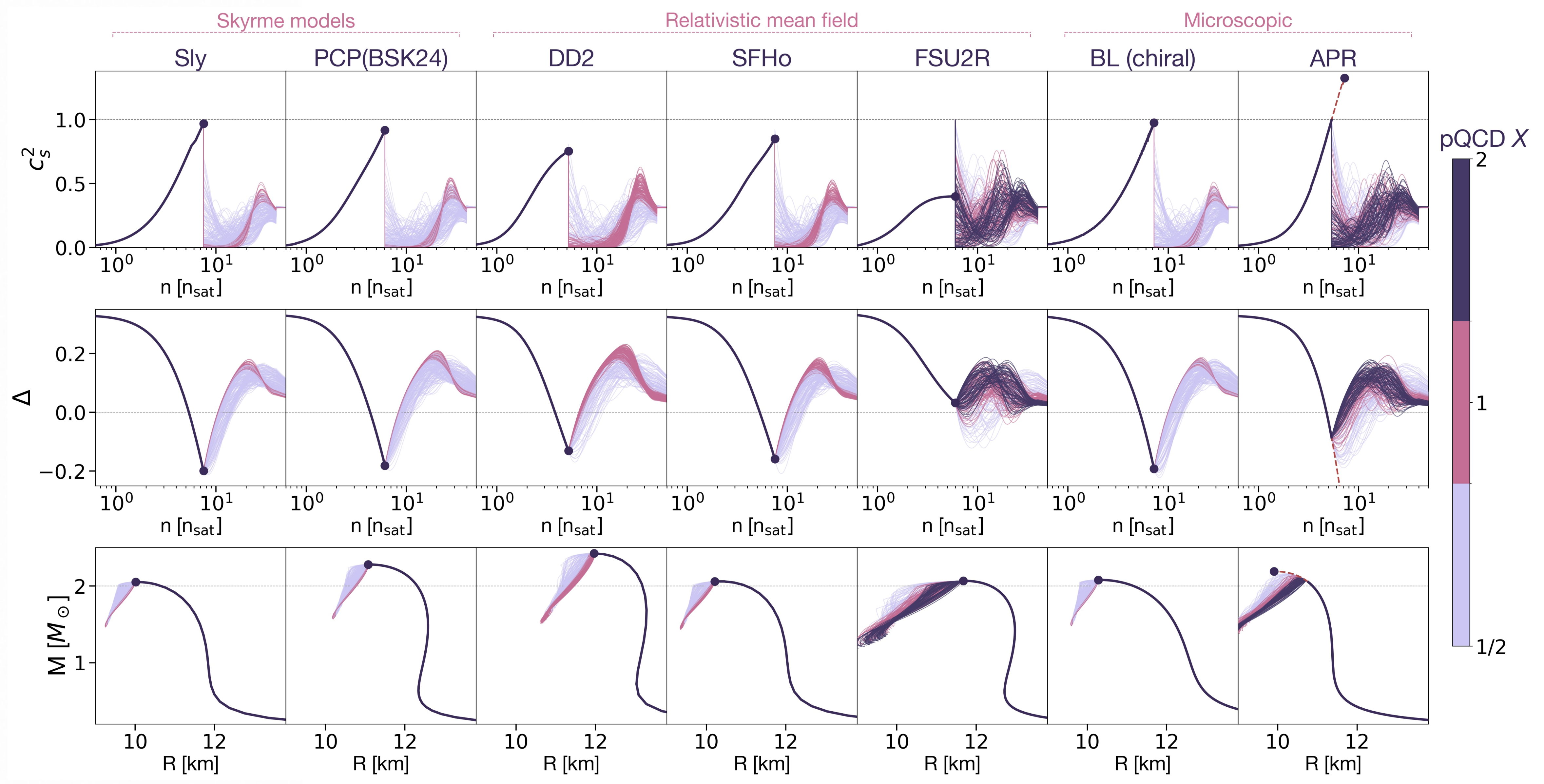
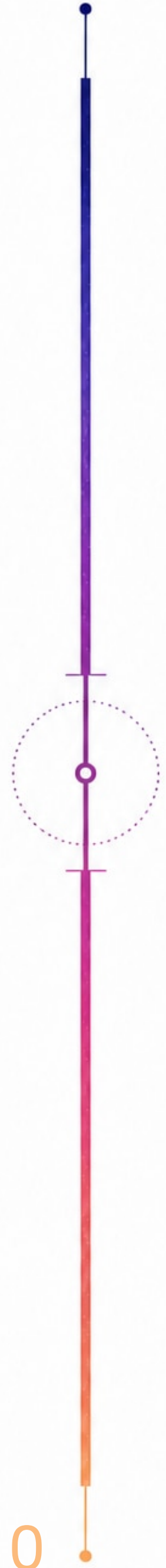
more than a mere prior

physically motivated framework



constrained Gaussian-process bridge





conclusions

new framework for neutron-star EoS inference

- nonparametric prior
- physically motivated
- maximally general
- no intermediate likelihoods
- no shooting procedure
- most efficient
- transparent tuning of correlation length

global anticorrelation in sounds speed

hadronic models require radical softening at the maximal NS density

