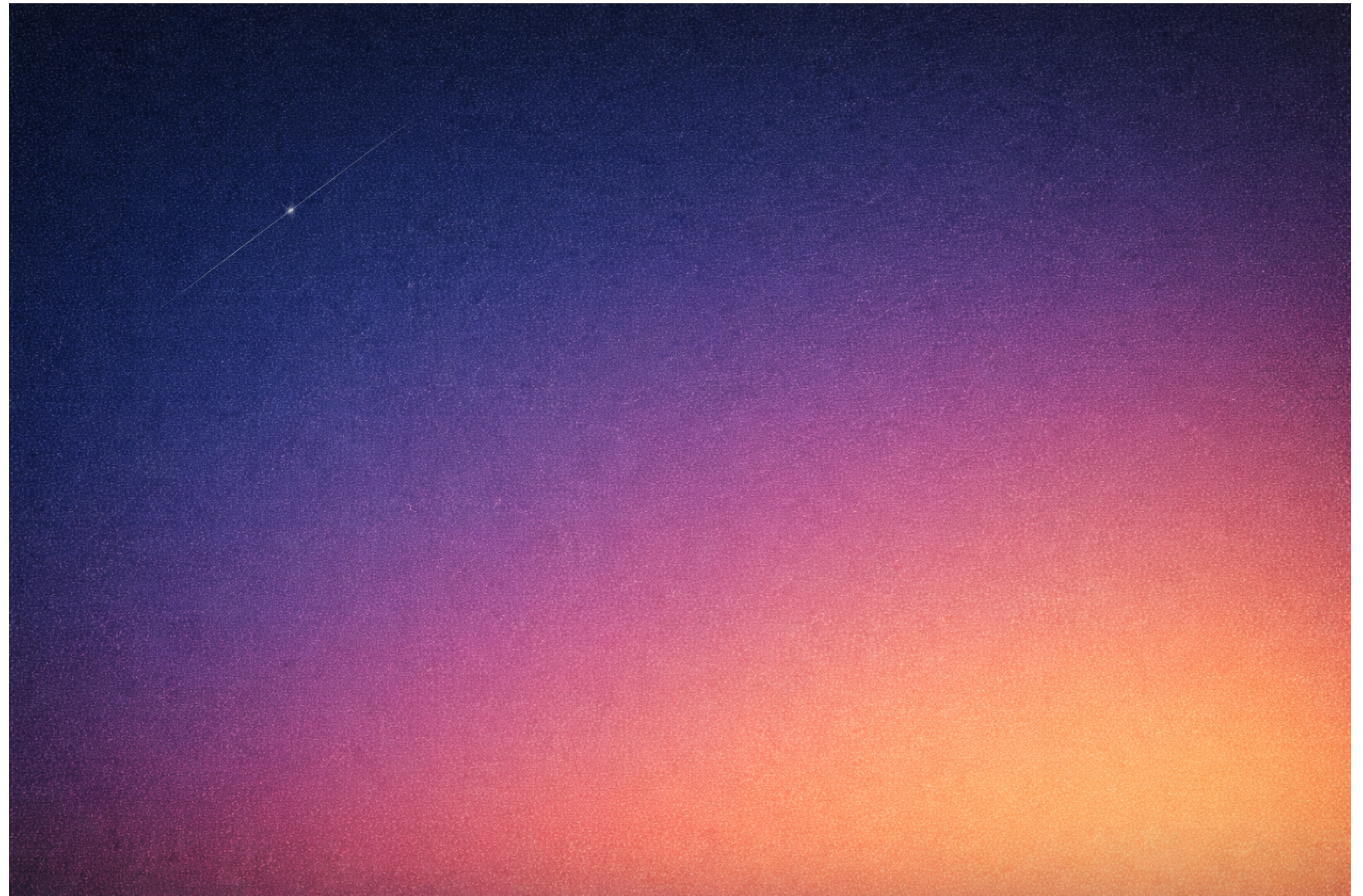


First-principles motivated prior for neutron-star equation-of-state inference

Oleg Komoltsev

CSQCD

May 2026



THE ASTROPHYSICAL JOURNAL

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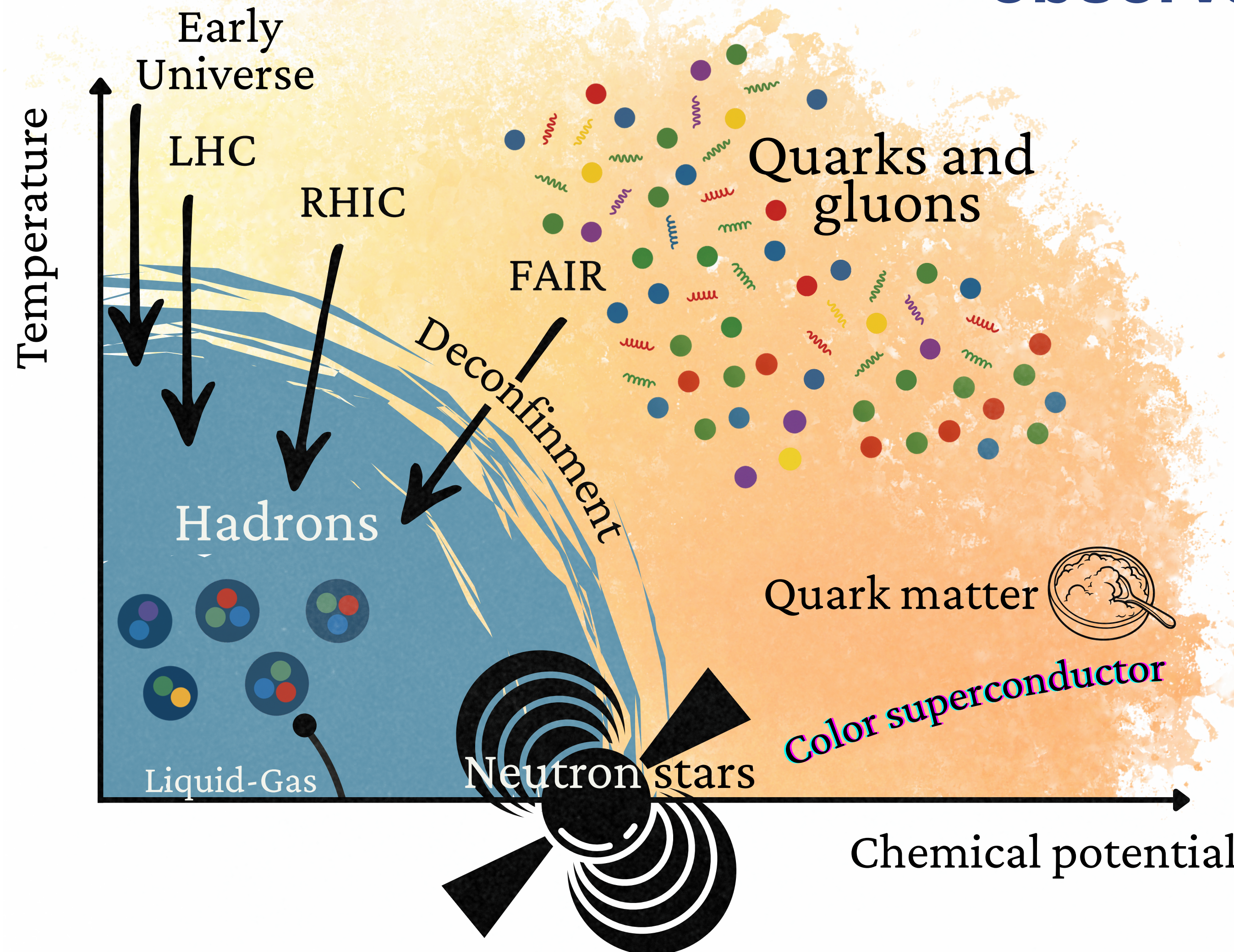
[The Astrophysical Journal](#), [Volume 1002](#), [Number 1](#)

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

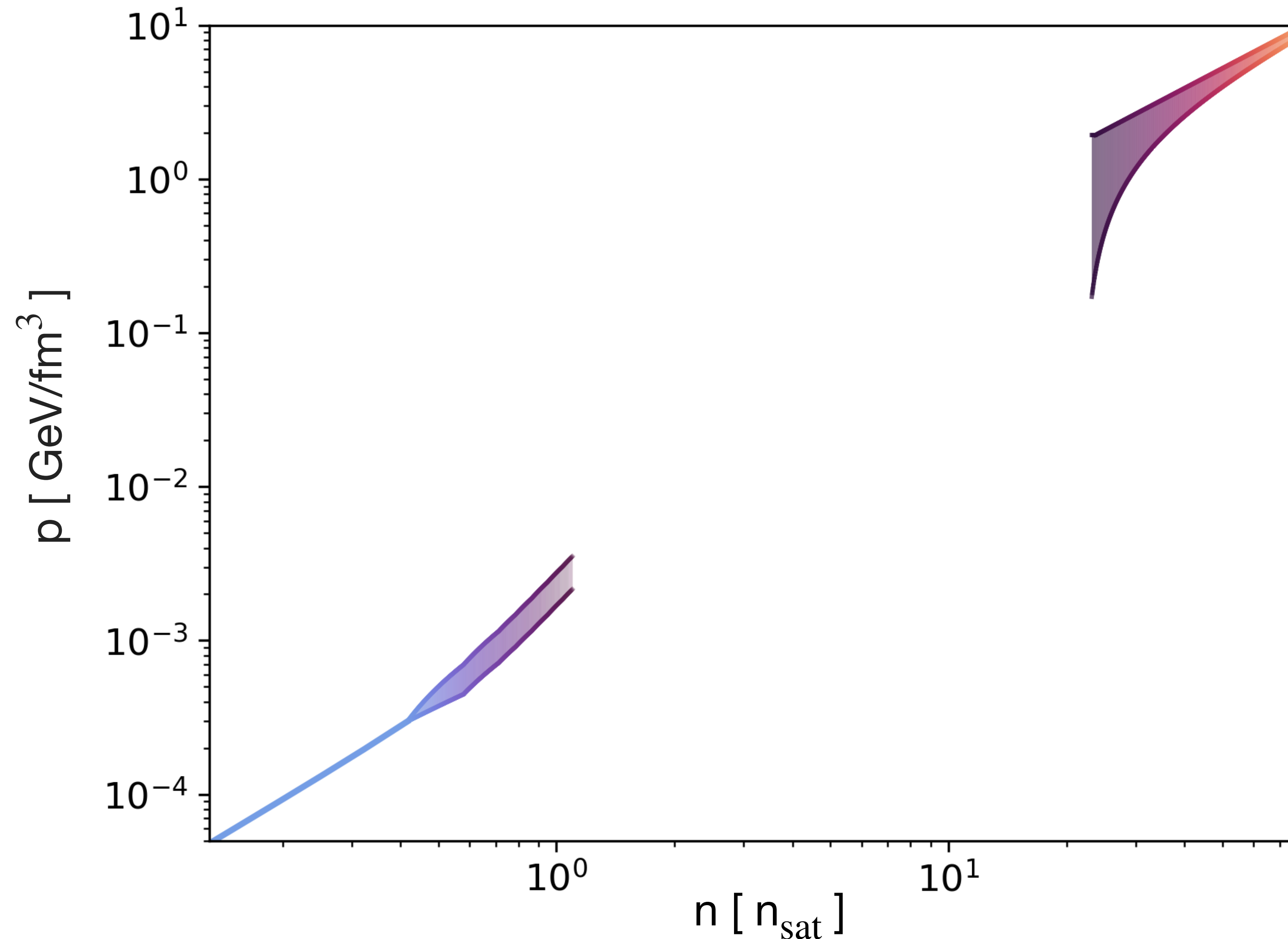
$$\frac{dp}{dr} = -\frac{Gm}{r^2} \varepsilon \left(1 + \frac{p}{\varepsilon} \right) \left(1 + \frac{4\pi r^3 \varepsilon}{m} \right) \left(1 - \frac{2Gm}{r} \right)^{-1}$$

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

equation of state

$$p(\varepsilon)$$

EoS from the first principles



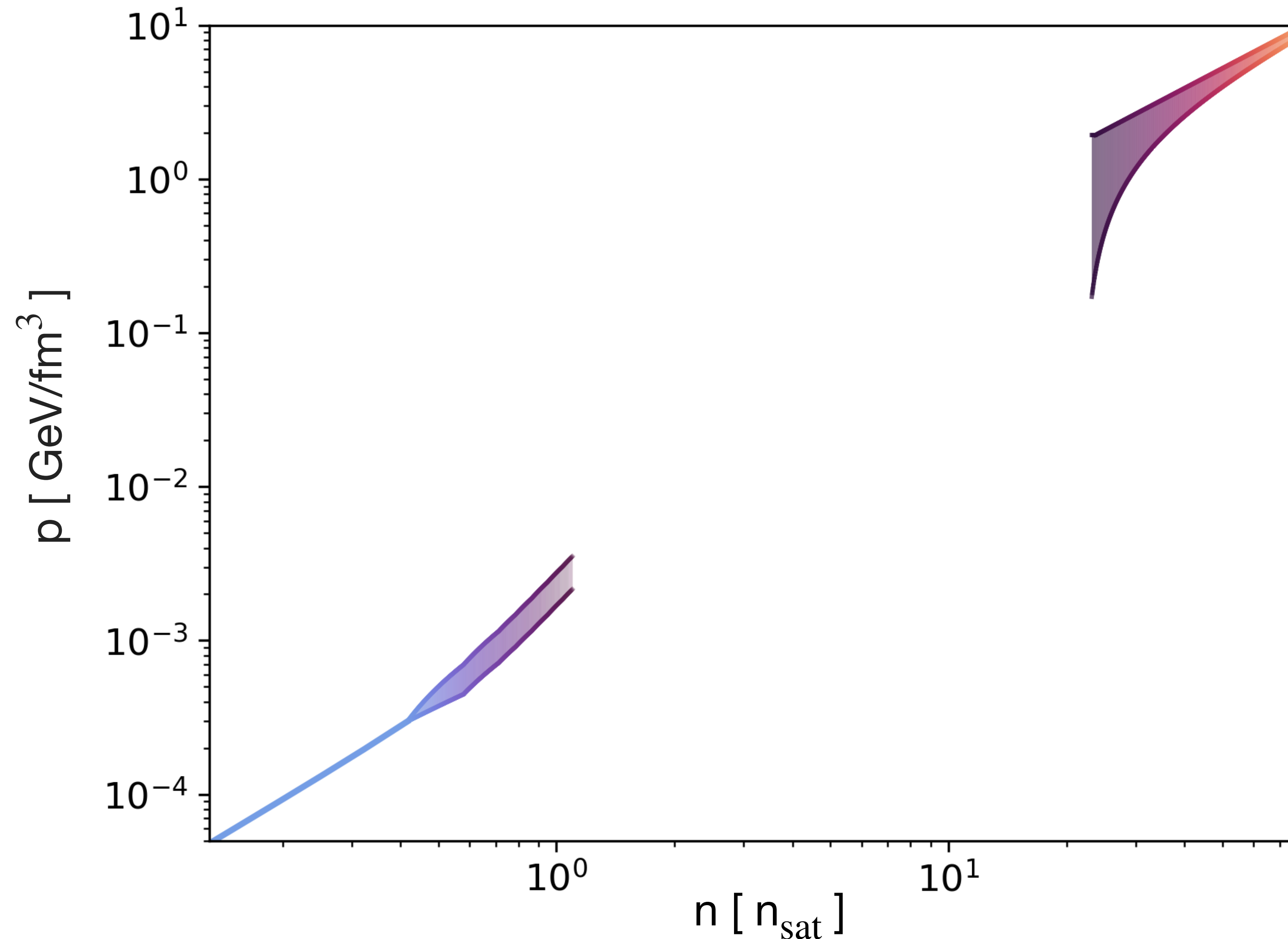
perturbative QCD
(pQCD)

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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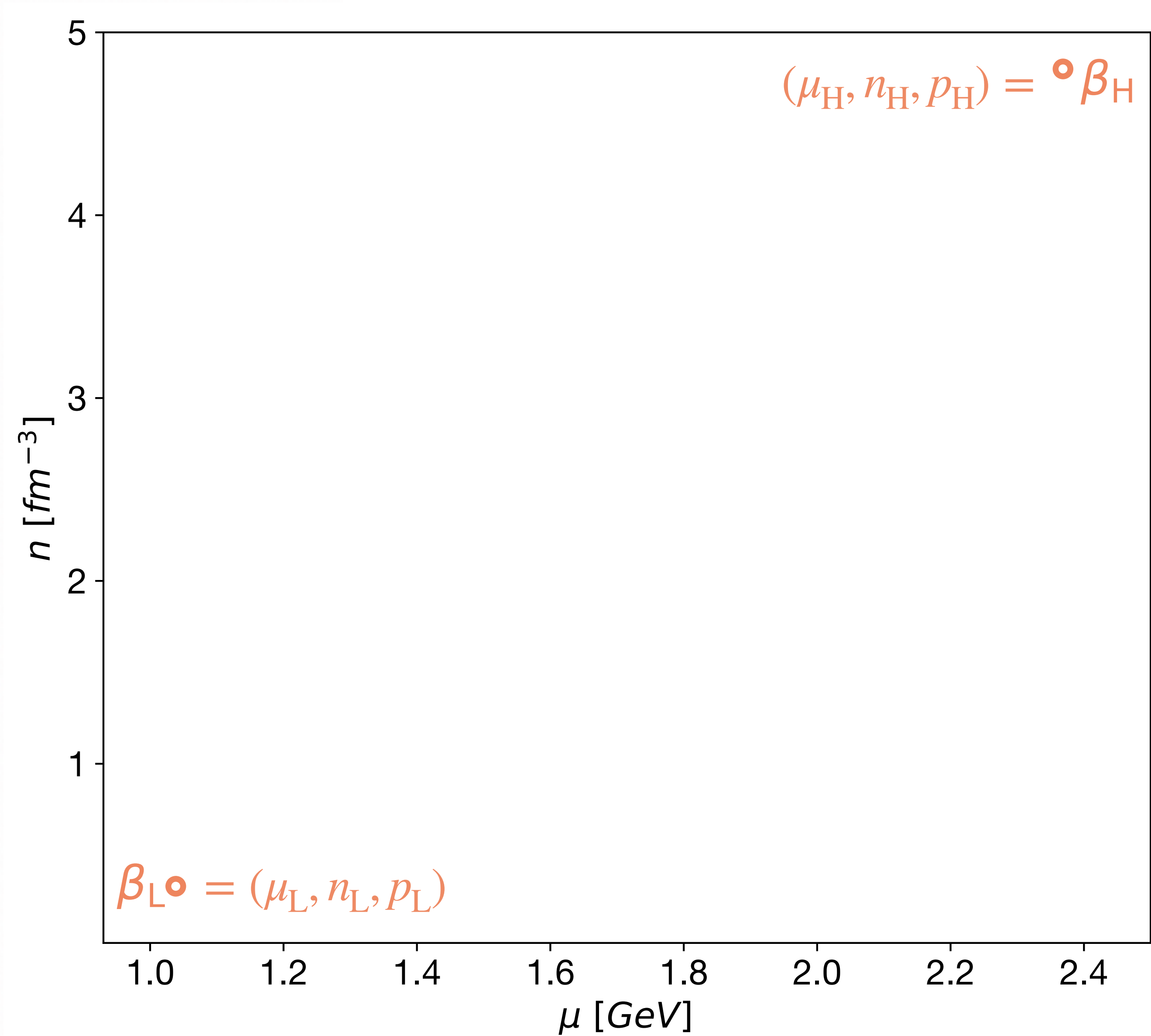
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Phys. Rev. Lett. 127, 162003

polytropic interpolation
 c_s^2 segments
Gaussian processes
GPB ← this talk

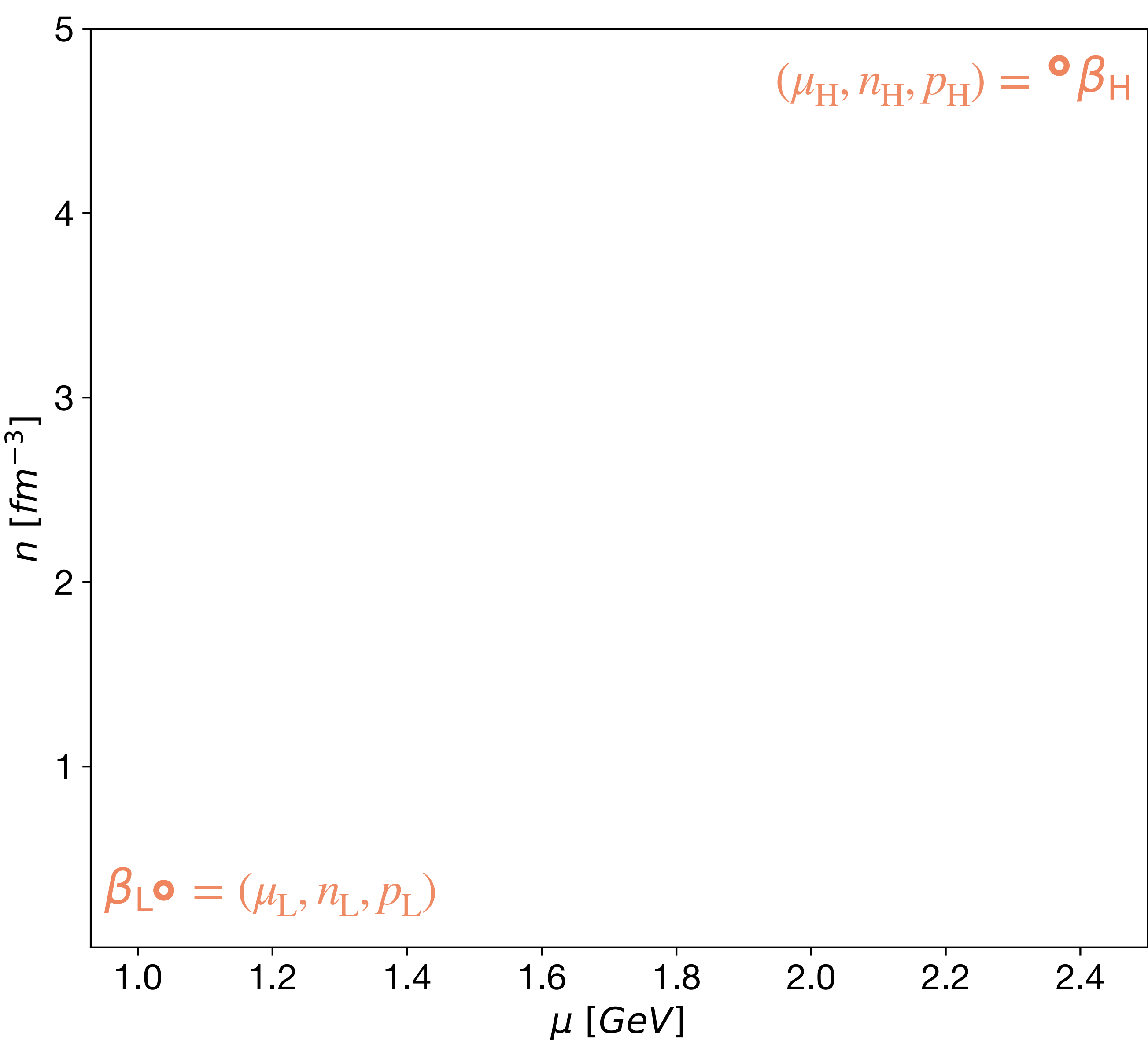
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self-similar [fractal] EoS



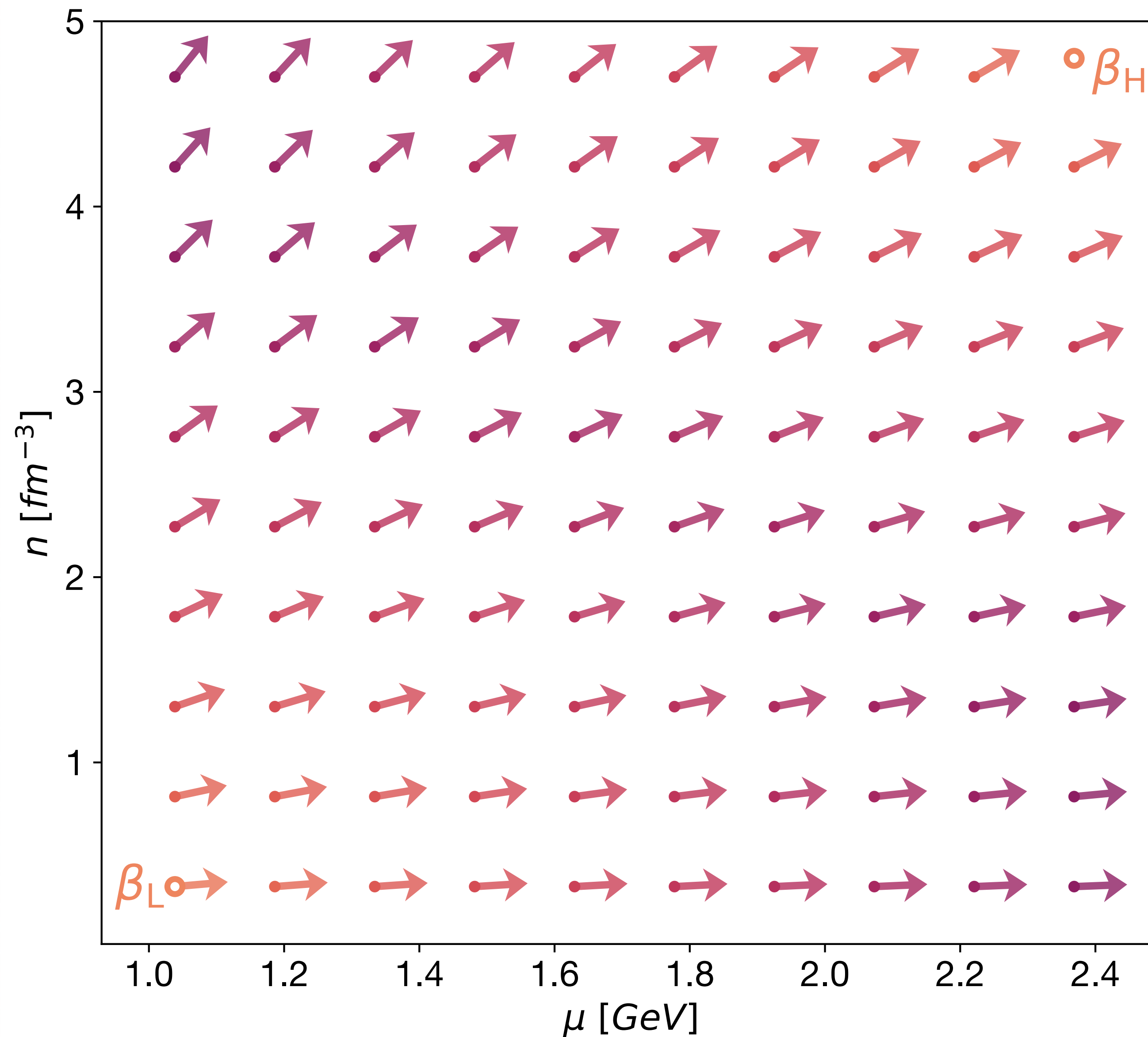
self-similar [fractal] EoS



stability

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

self-similar [fractal] EoS



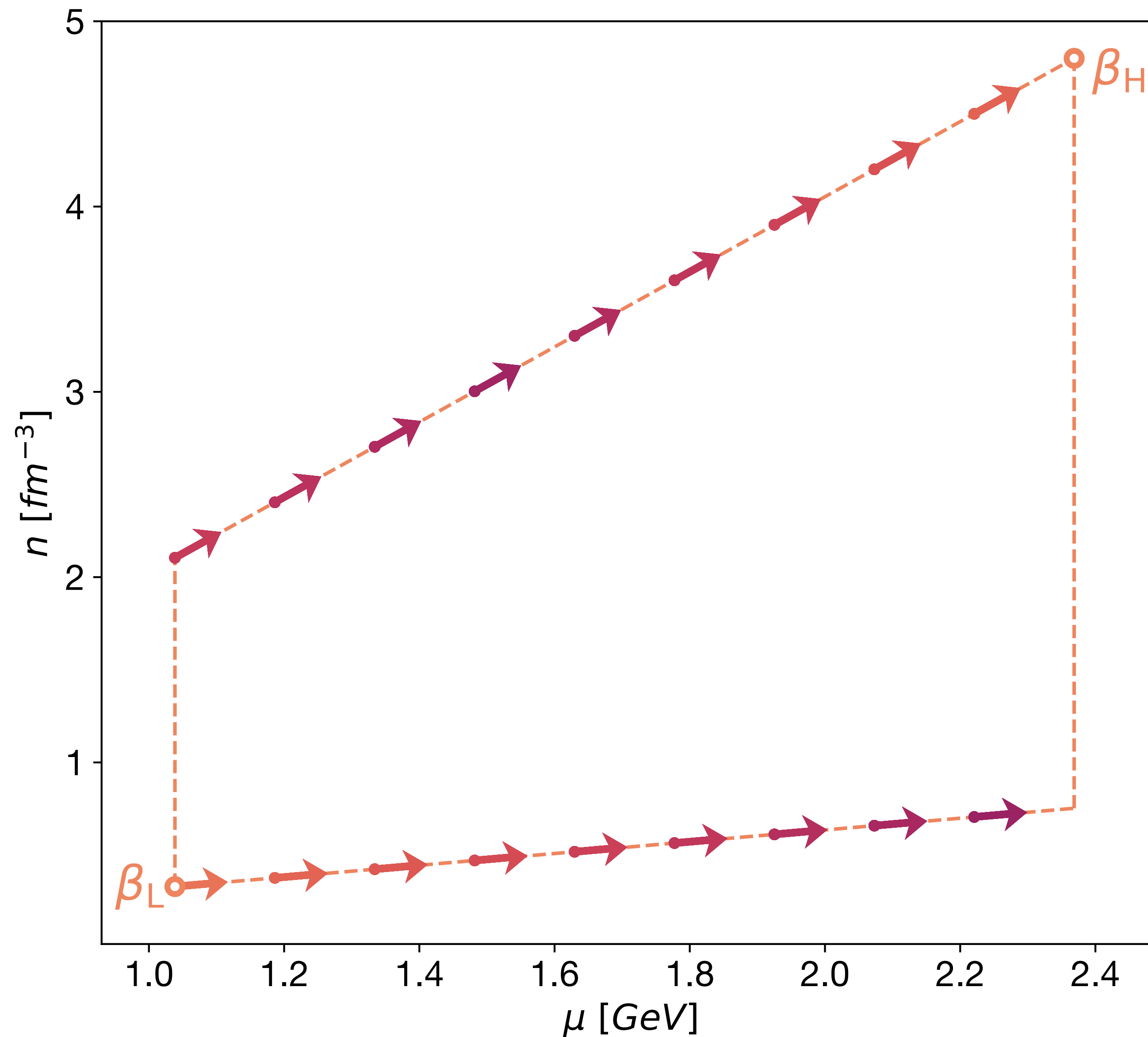
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$$\partial_\mu^2 \Omega(\mu) \leq 0 \implies \partial_\mu n(\mu) \geq 0$$

causality

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

self-similar [fractal] EoS



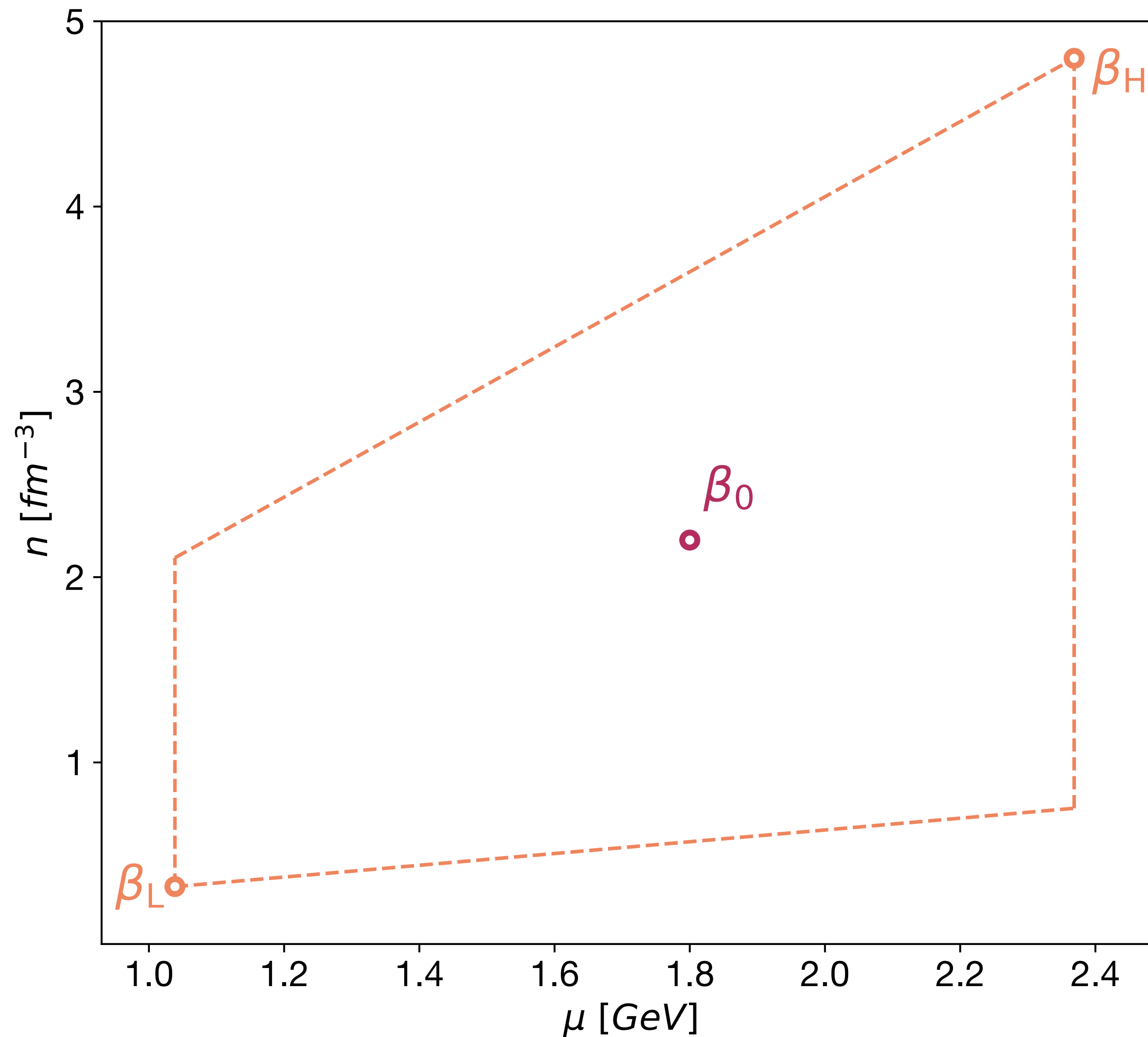
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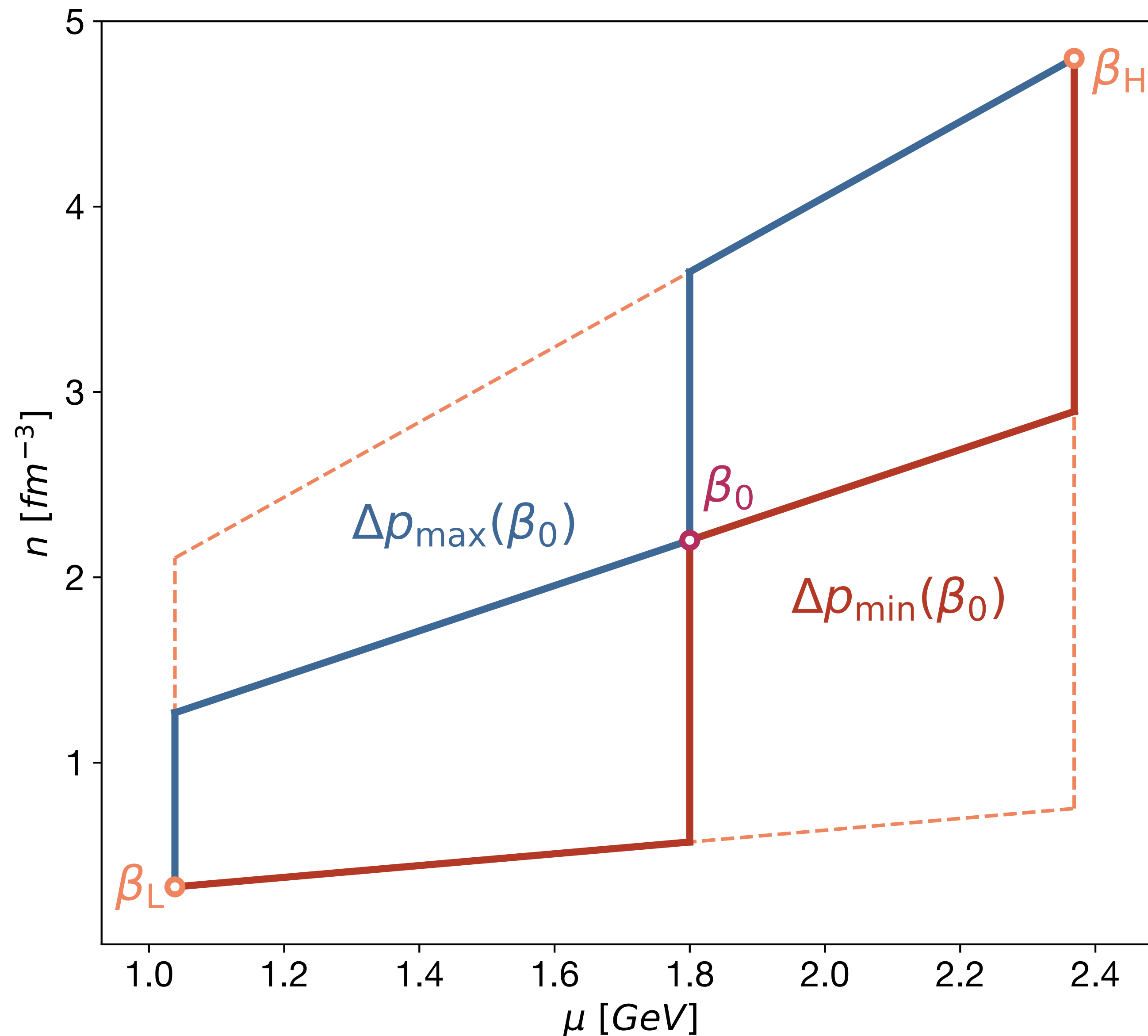
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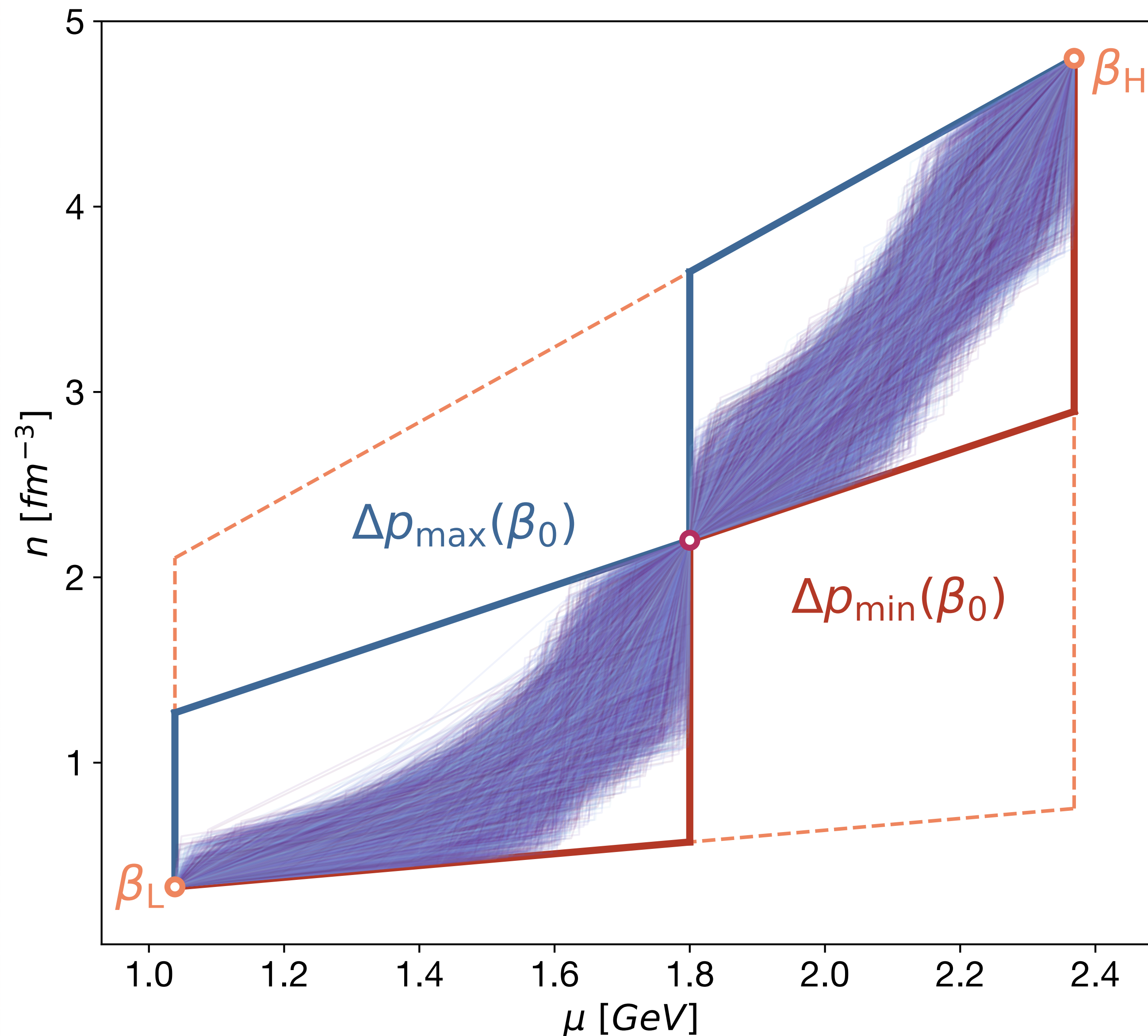
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consistency

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

self-similar [fractal] EoS



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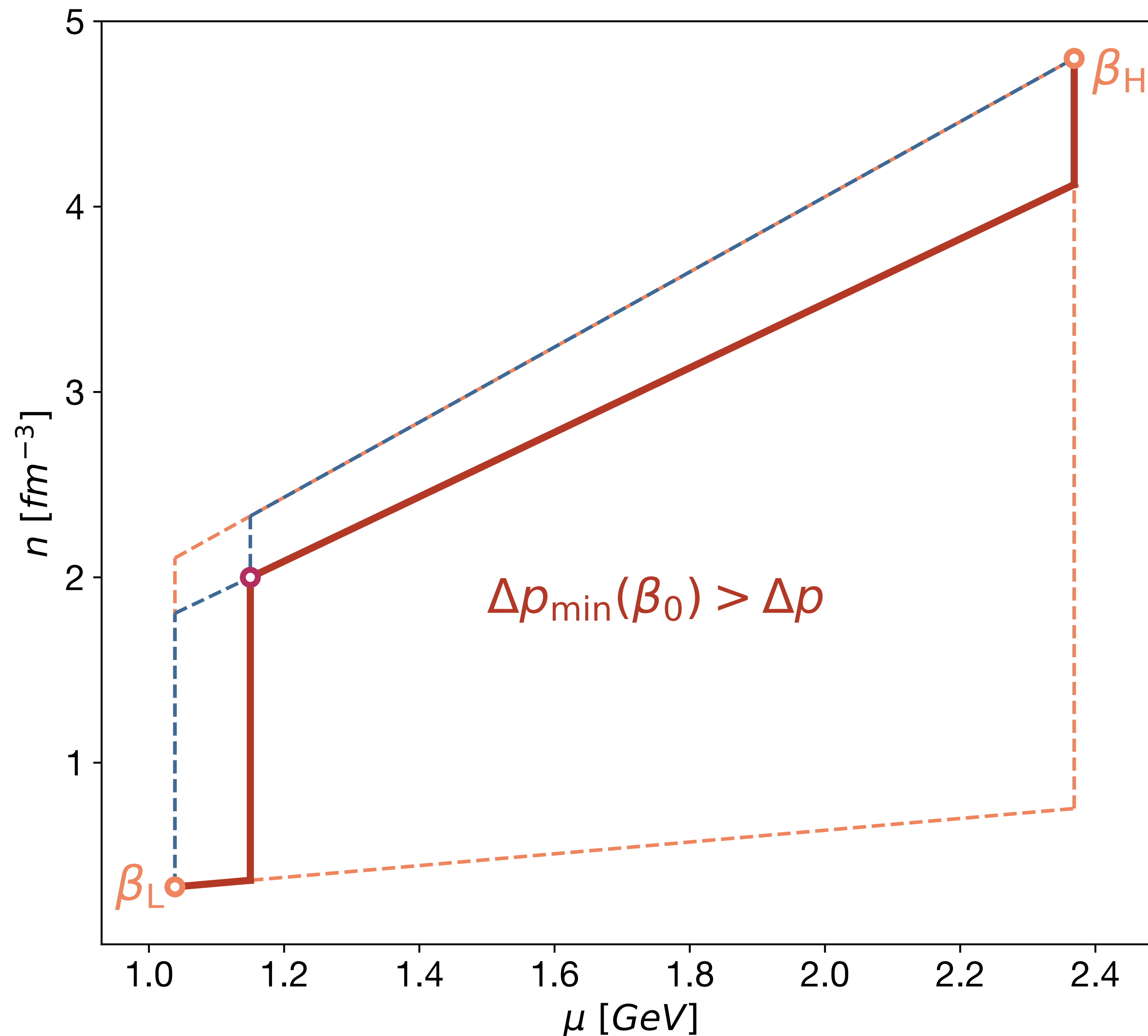
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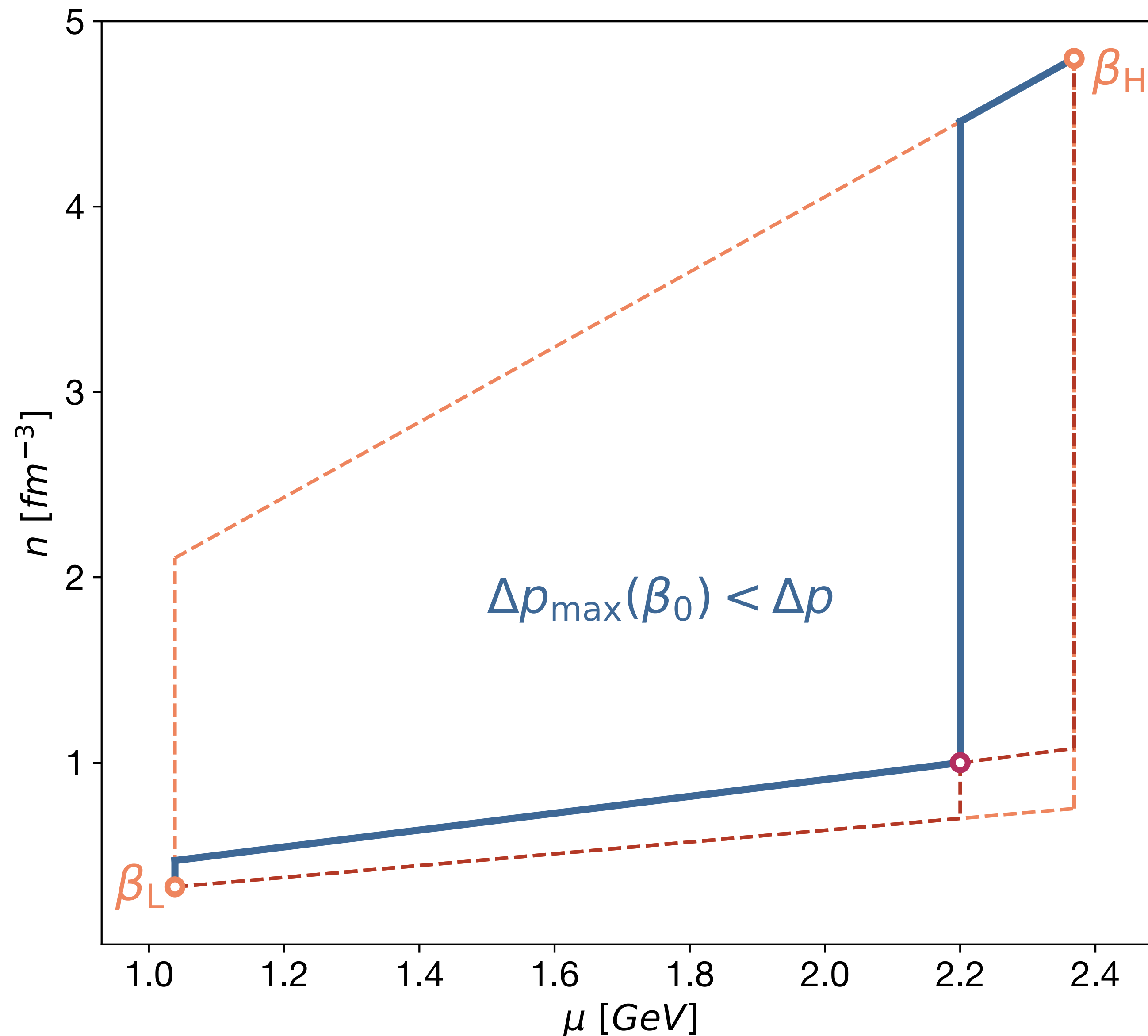
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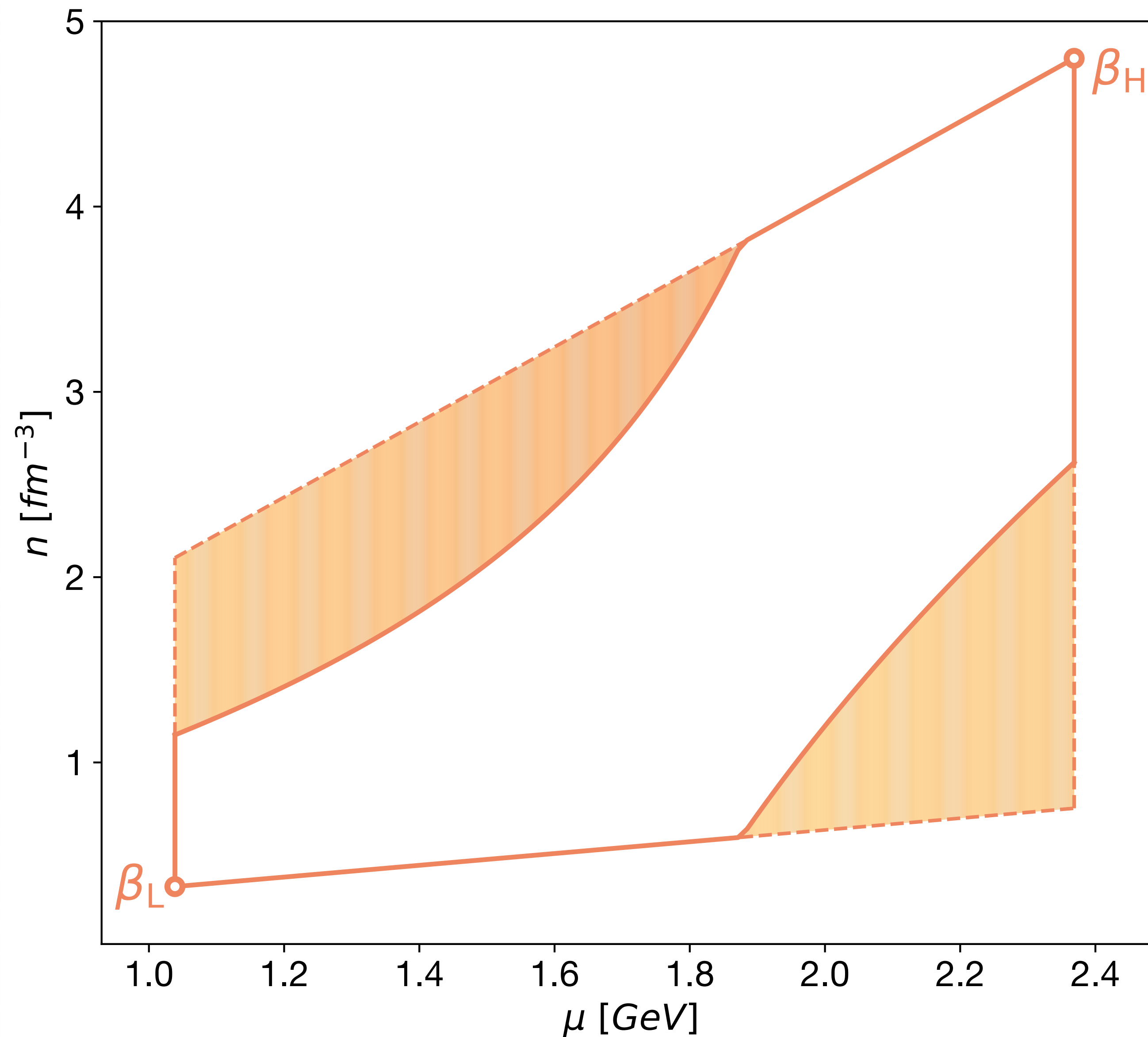
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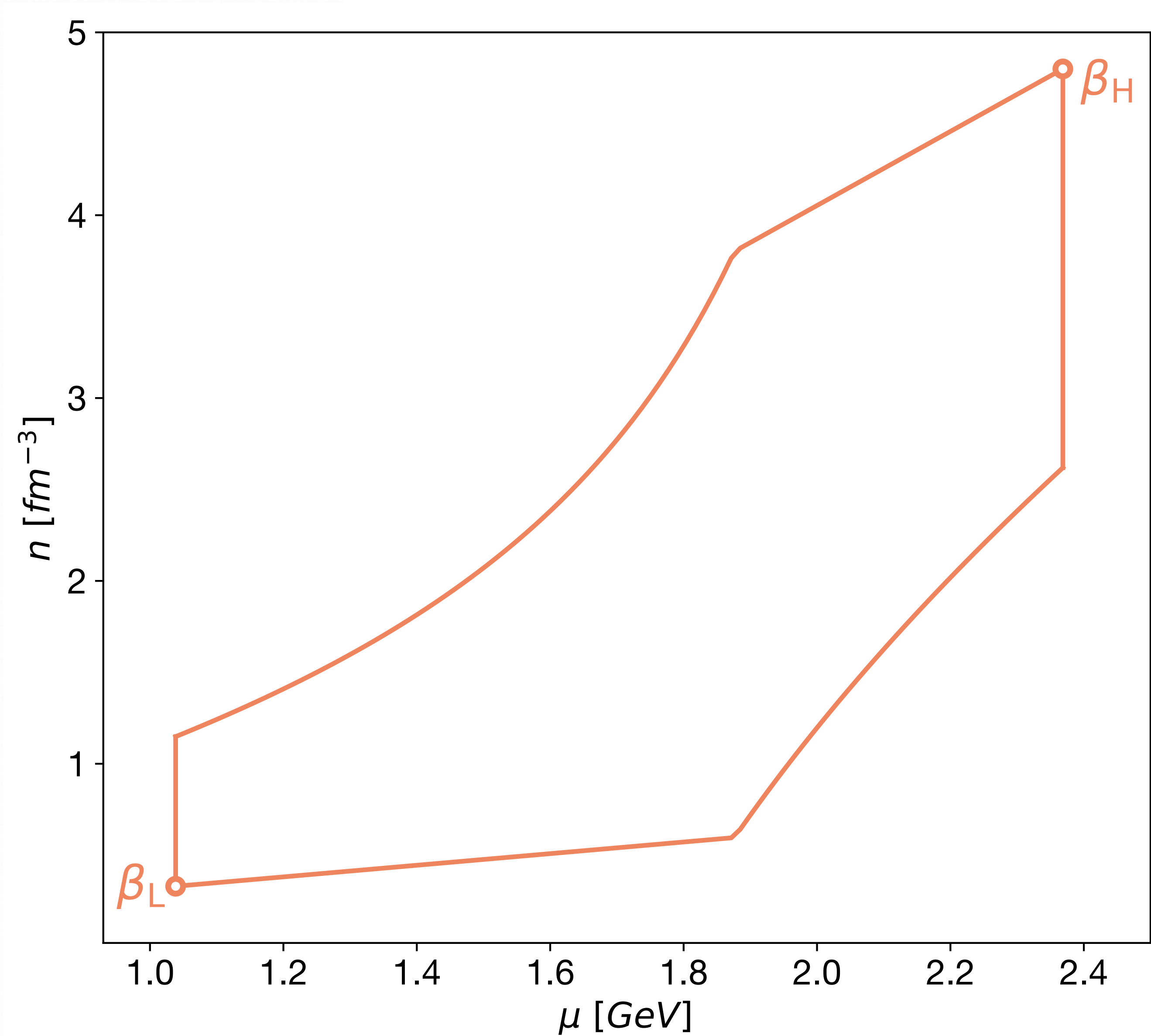
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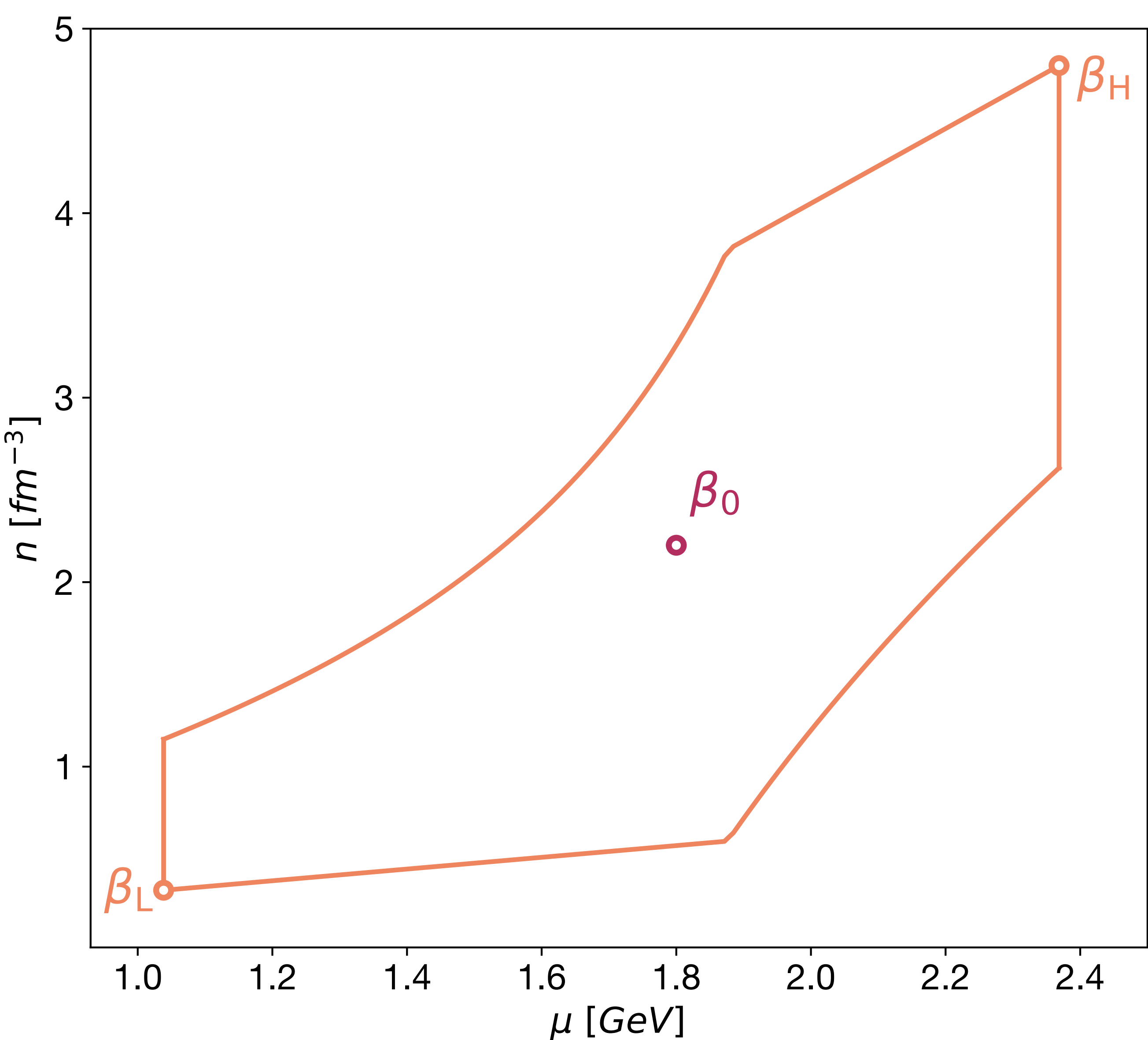
$$\int_{\mu_L}^{\mu_H} n(\mu) d\mu = p_L - p_H = \Delta p$$

self-similar [fractal] EoS

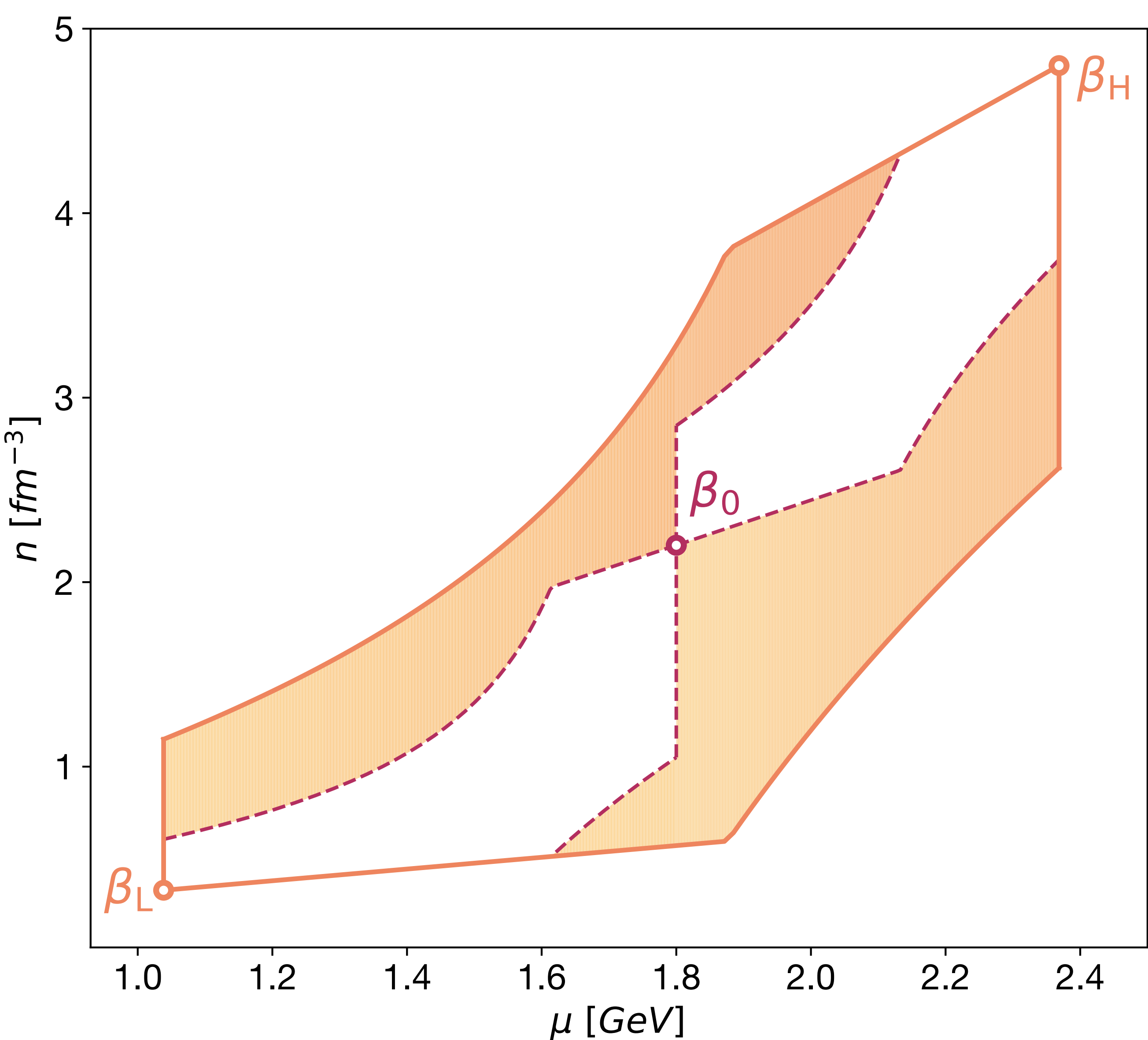


β_L, β_H are not special

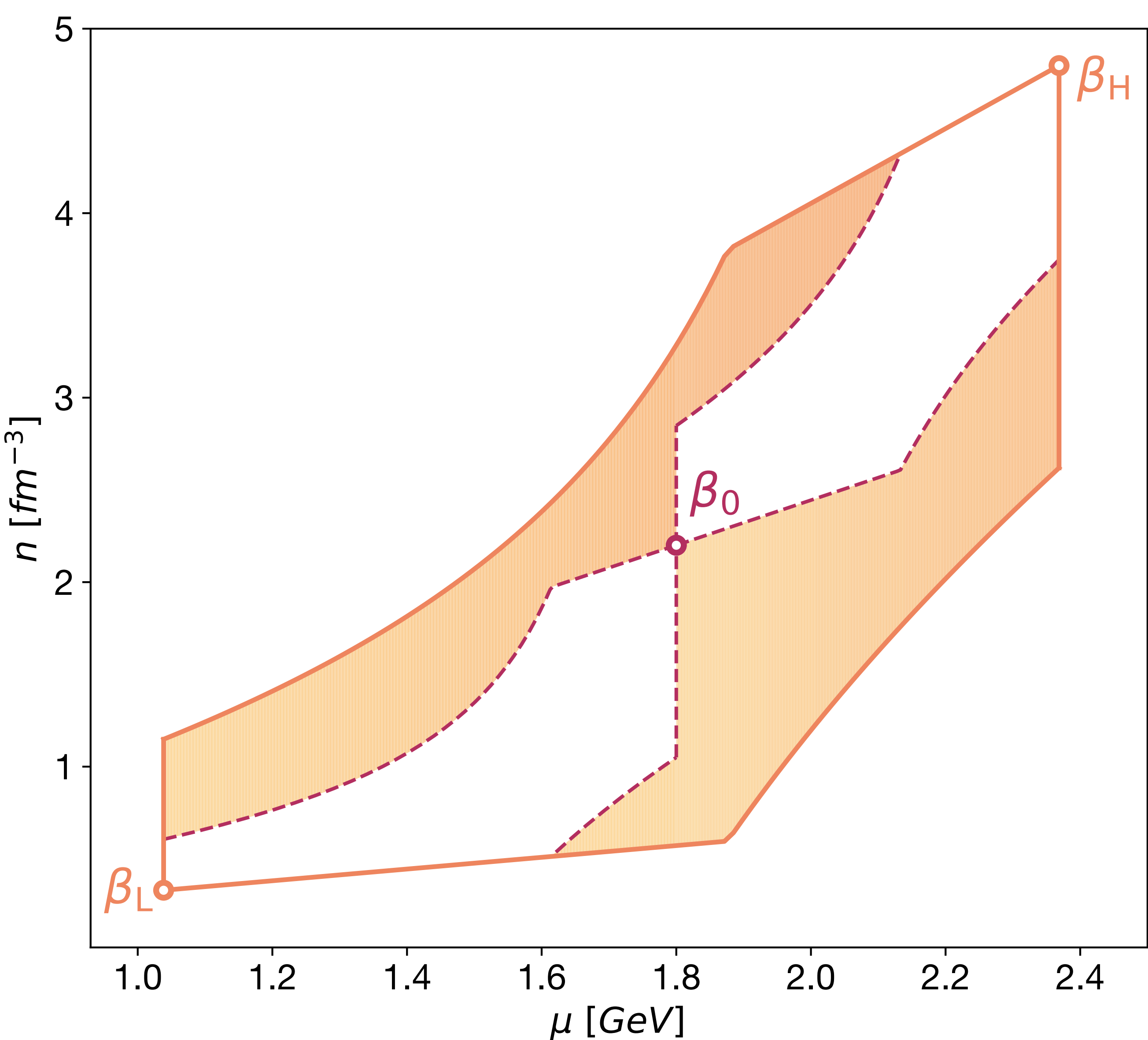
self-similar [fractal] EoS



self-similar [fractal] EoS

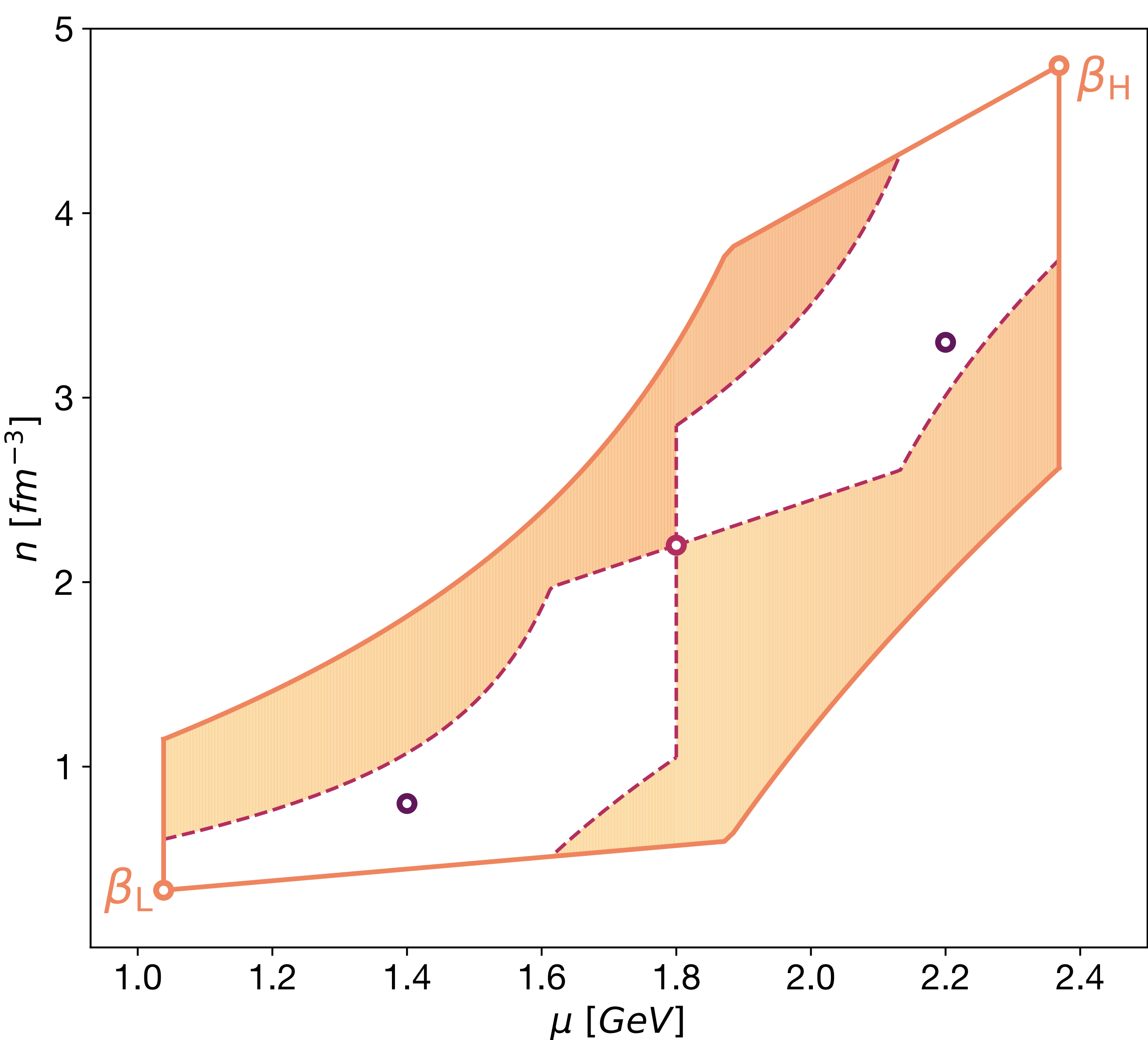


self-similar [fractal] EoS

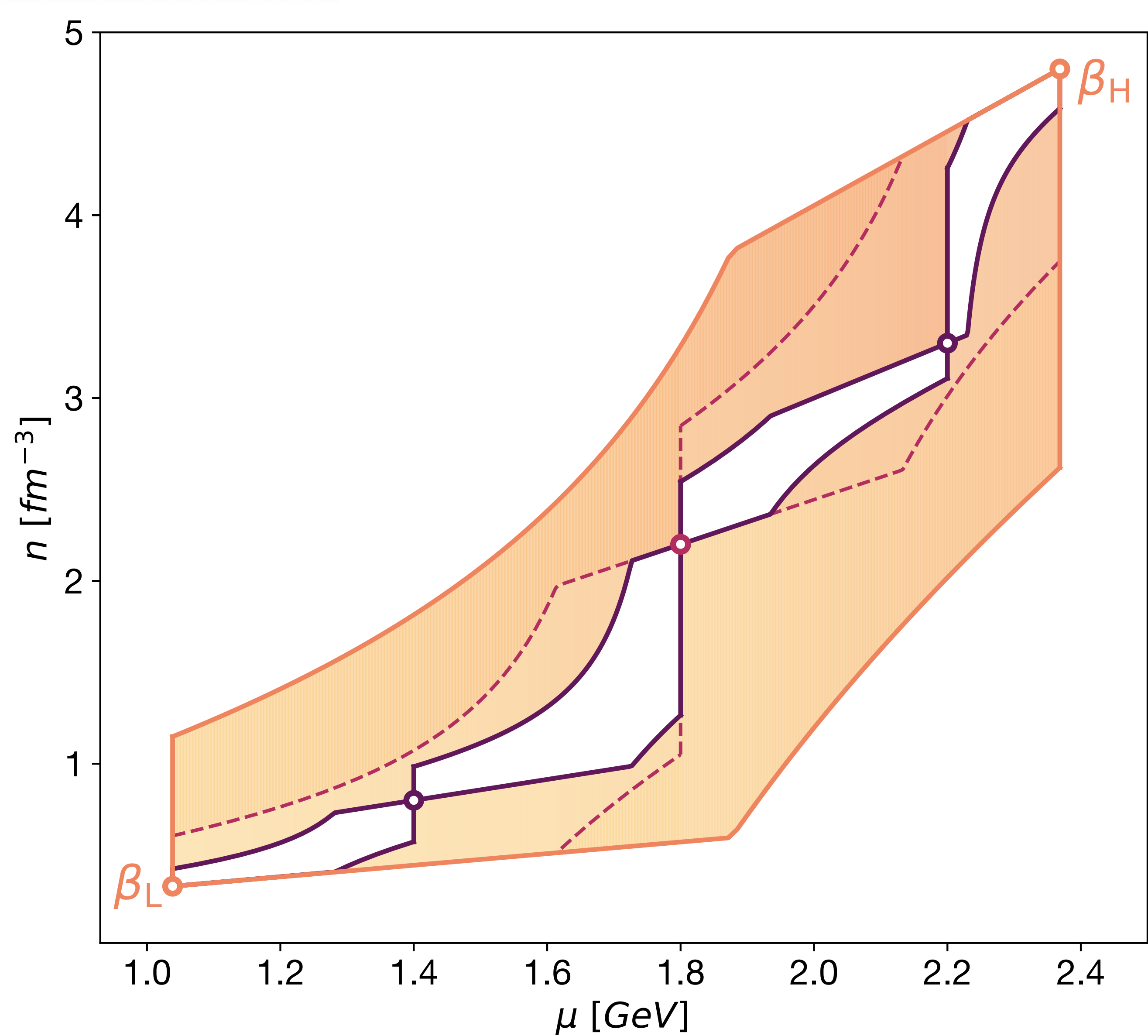


$\beta_L, \beta_0, \beta_H$ are not special

self-similar [fractal] EoS

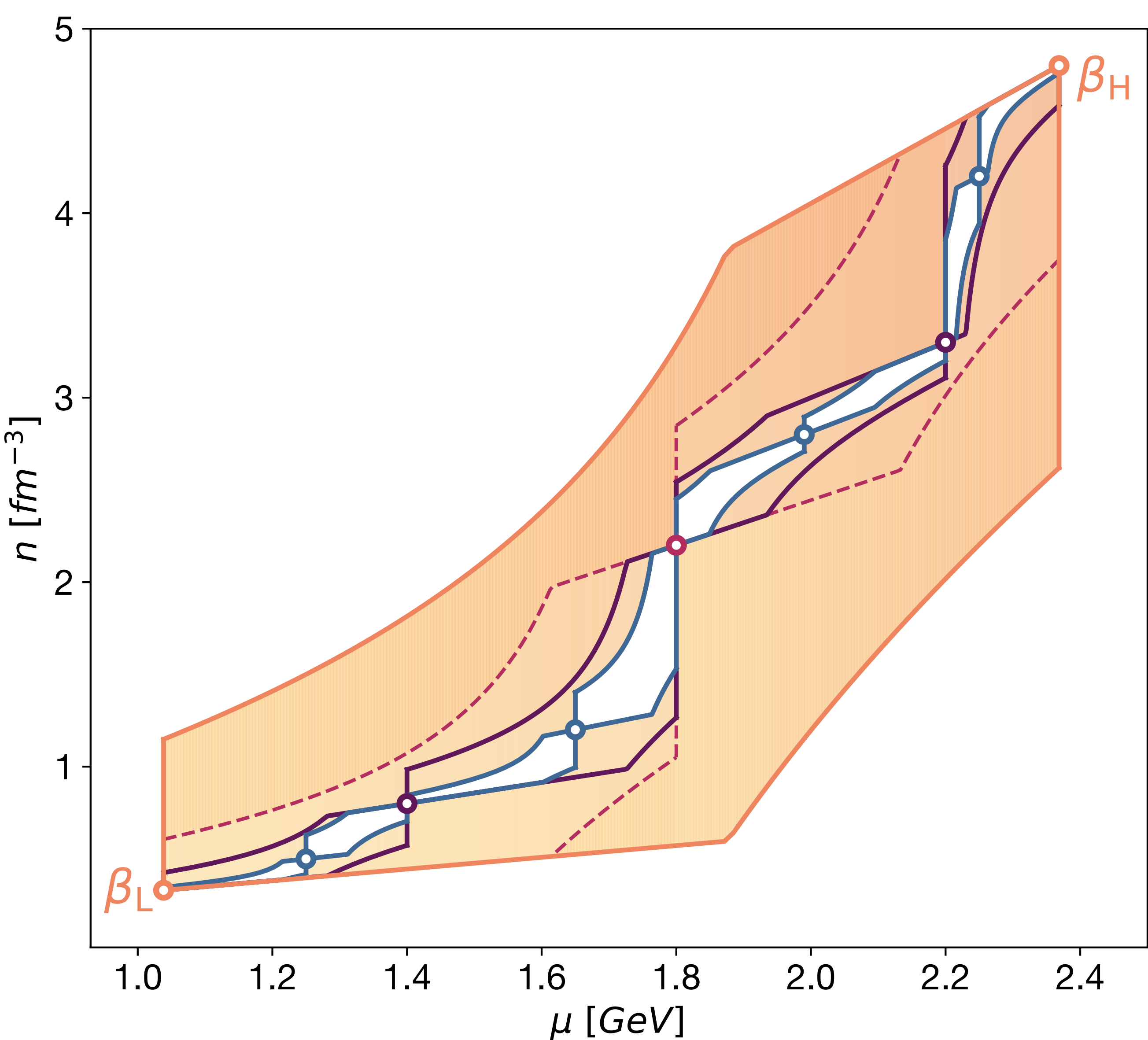


self-similar [fractal] EoS



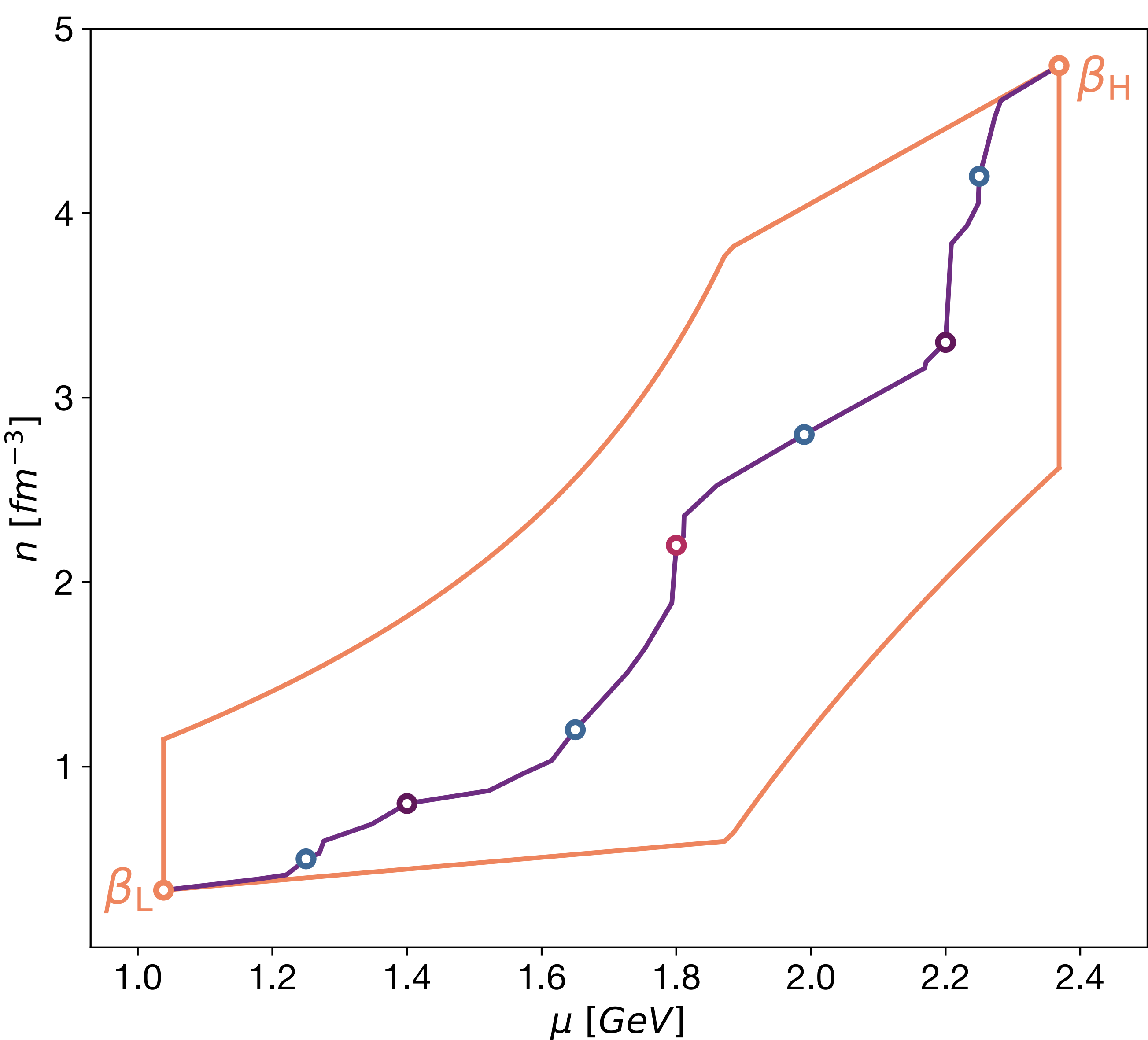
more

self-similar [fractal] EoS

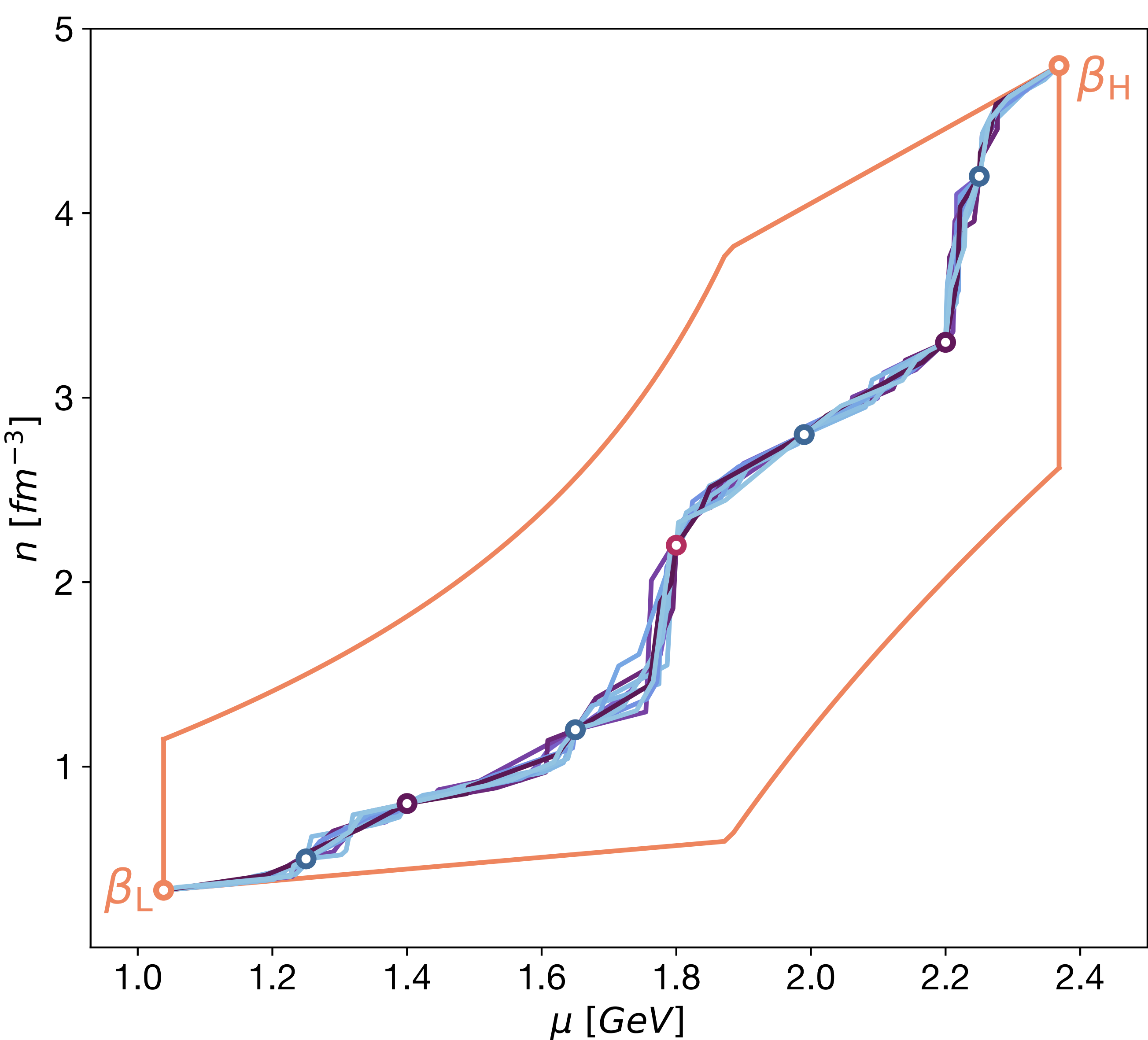


MORE

self-similar [fractal] EoS

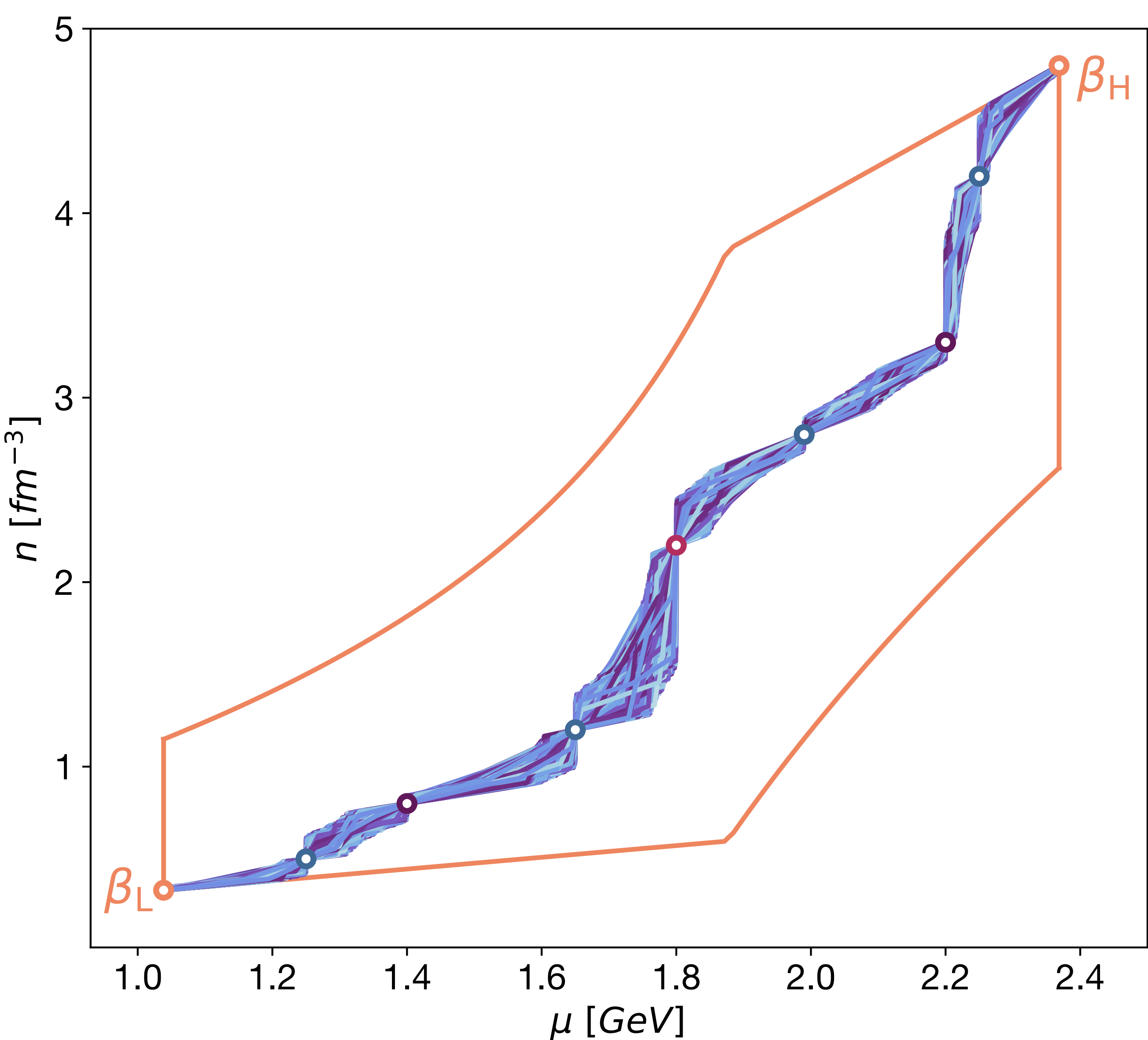


self-similar [fractal] EoS



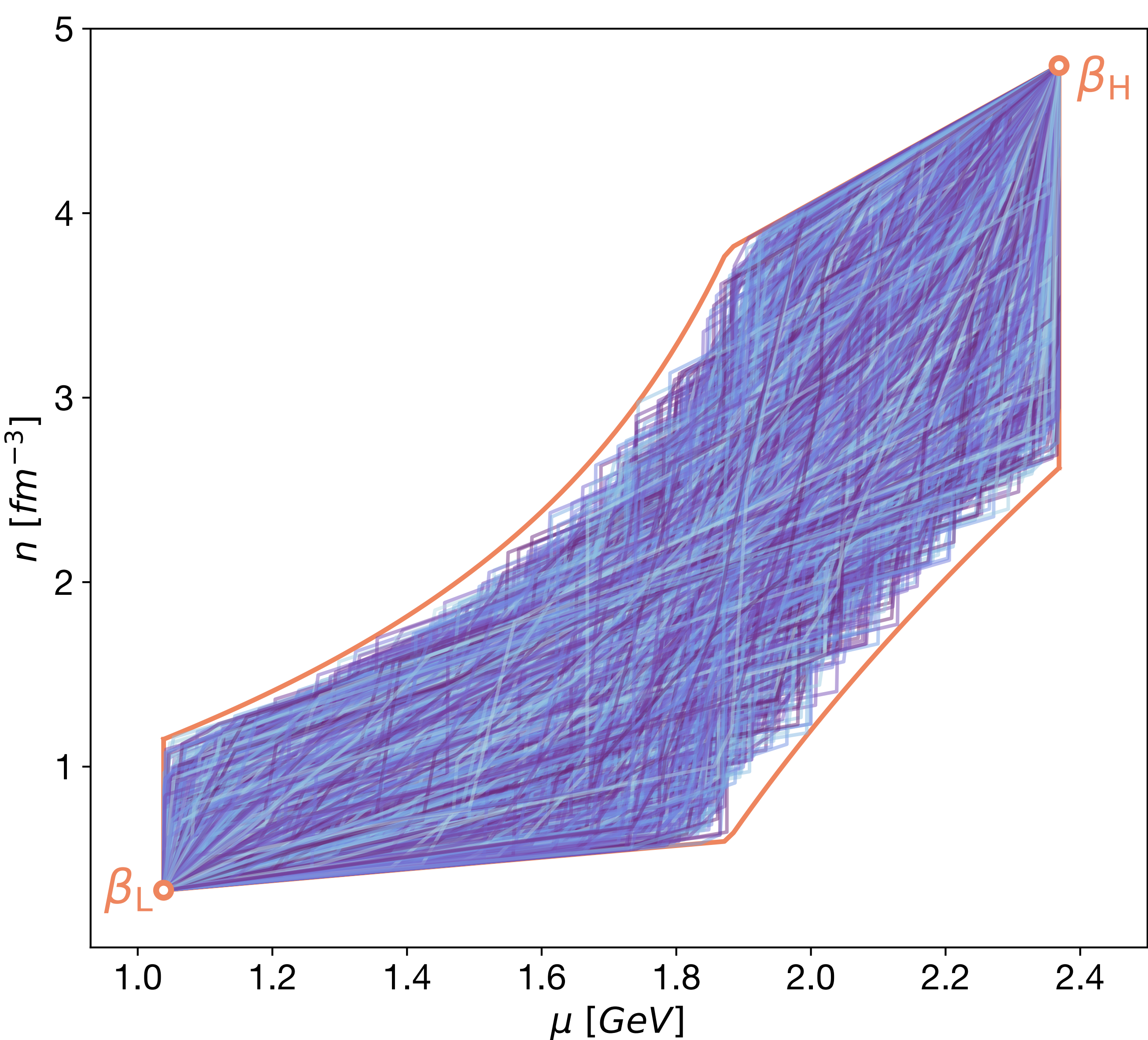
more

self-similar [fractal] EoS



MORE

self-similar [fractal] EoS



self-similar [fractal] EoS

$p \text{ [GeV/fm}^3 \text{]}$

2.5
2.0
1.5
1.0
0.5
0.0

$n \text{ [fm}^{-3} \text{]}$

5
4
3
2
1
0

$\mu \text{ [GeV]}$

2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0

volume is uniformly sampled

introducing local Gaussian correlation

the diffusion equation

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

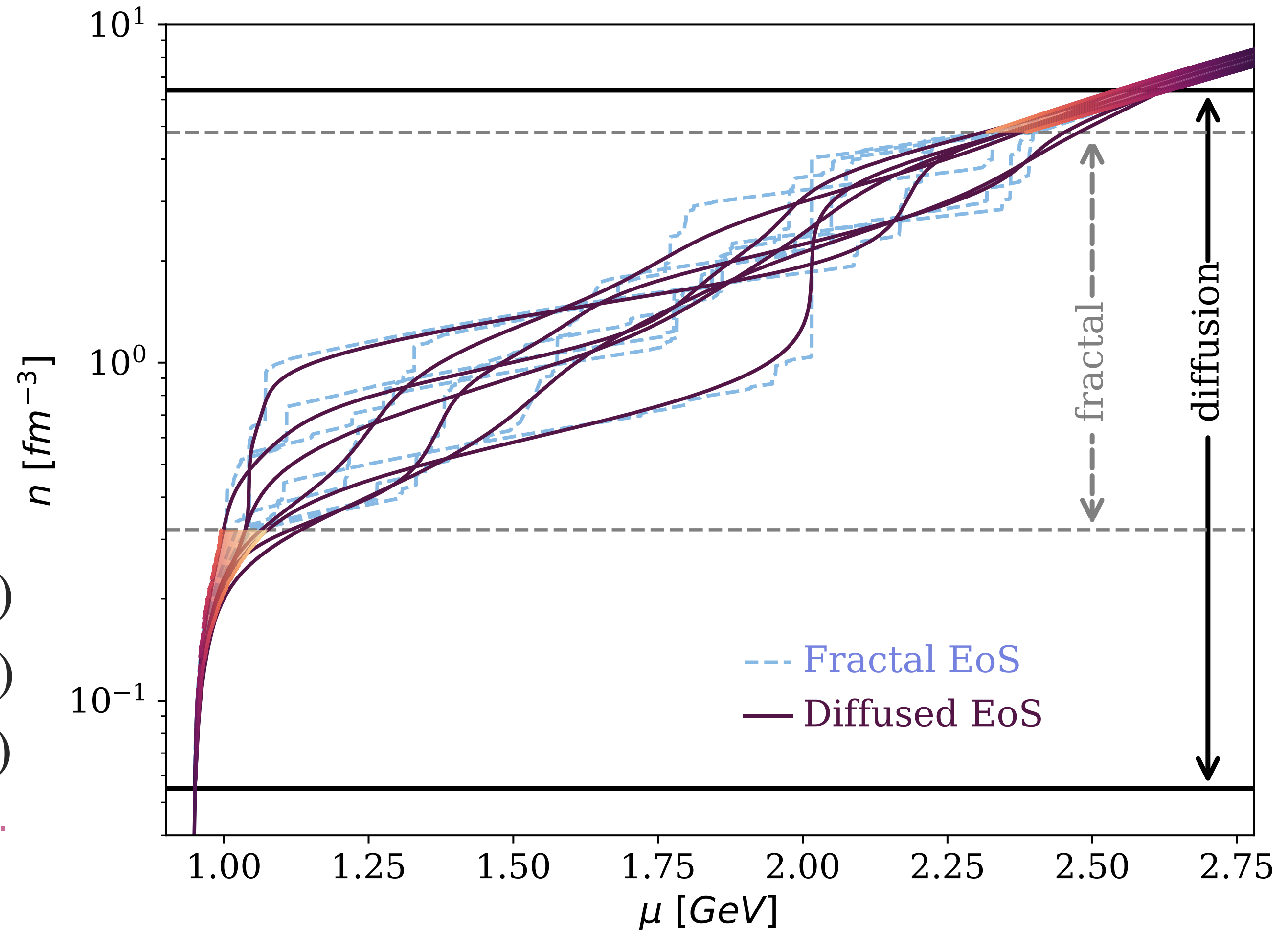
unphysical time flow $\mu(n) \rightarrow \mu(n, \tau)$

density-dependent coefficient $D(n)$

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

Dirichlet boundary conditions

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



introducing local Gaussian correlation

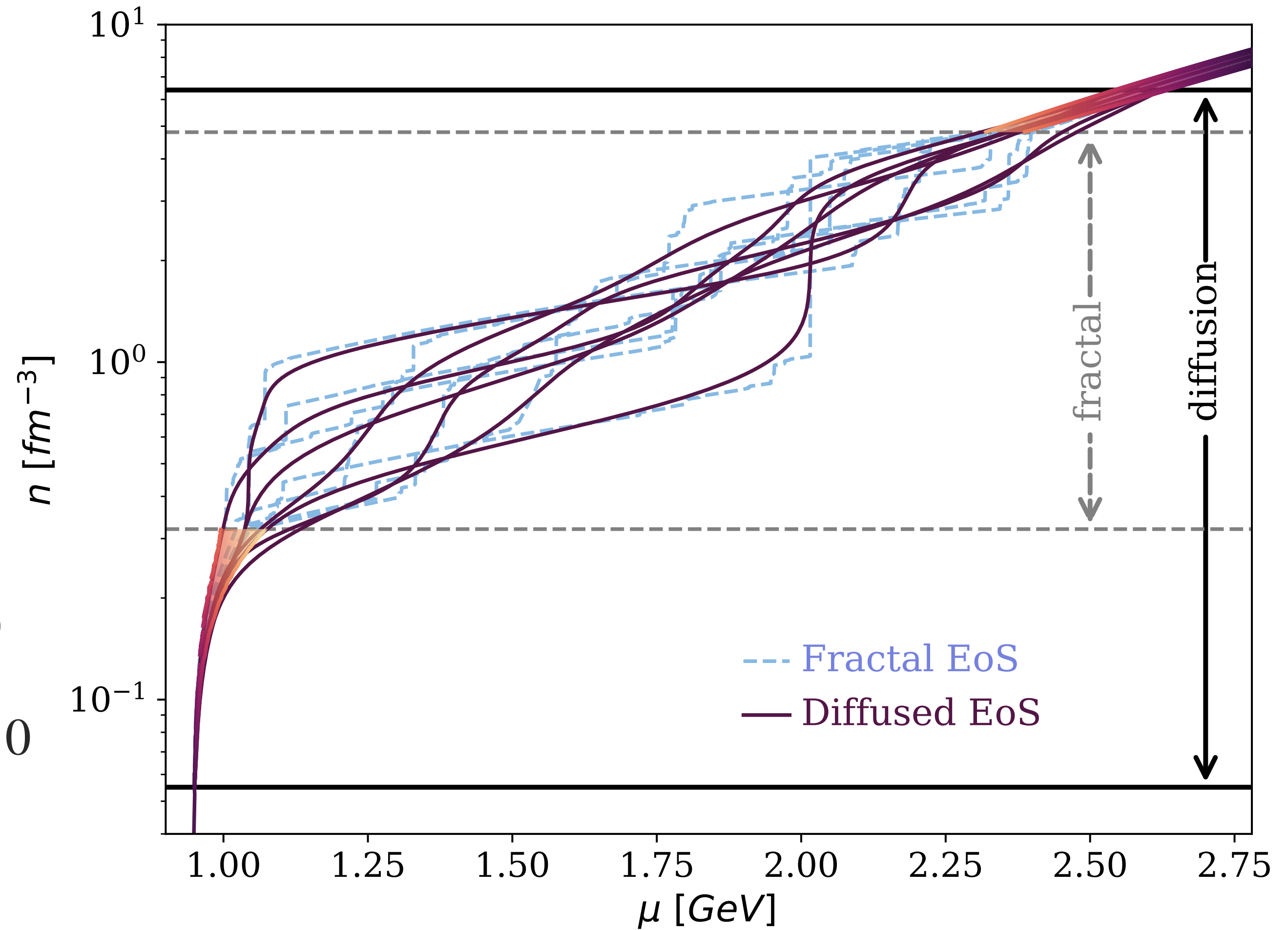
the diffusion equation

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

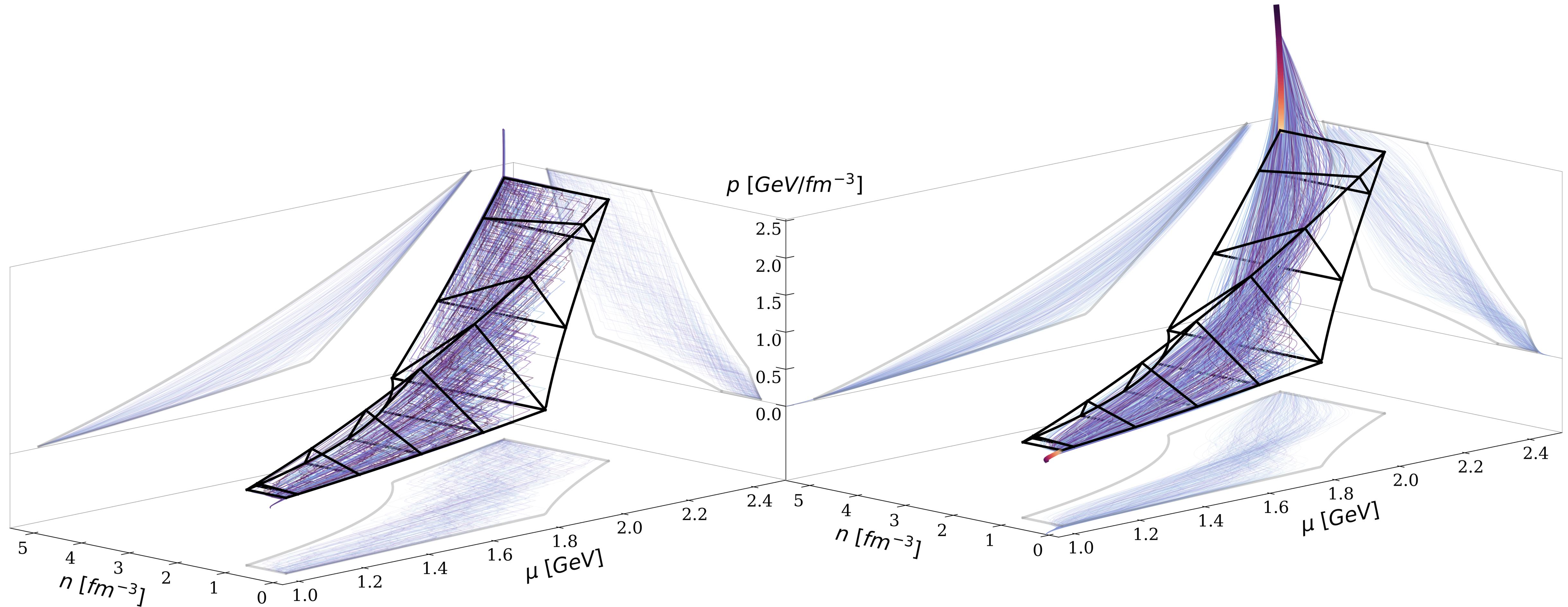
stability $\partial_n \mu(n, 0) > 0$ & $D(n) > 0$

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

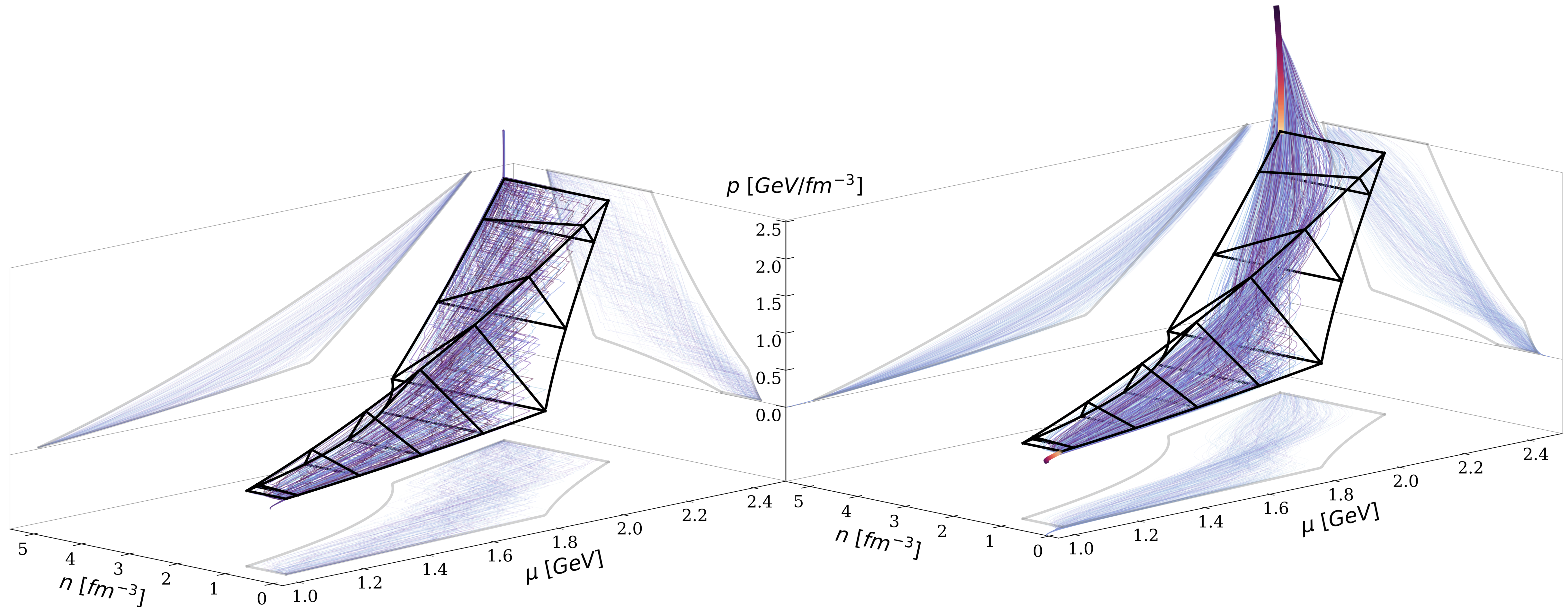
consistency $\varepsilon' - \varepsilon = \int_n^{n'} \mu(n) dn$



constrained Gaussian-process bridge



constrained Gaussian-process bridge

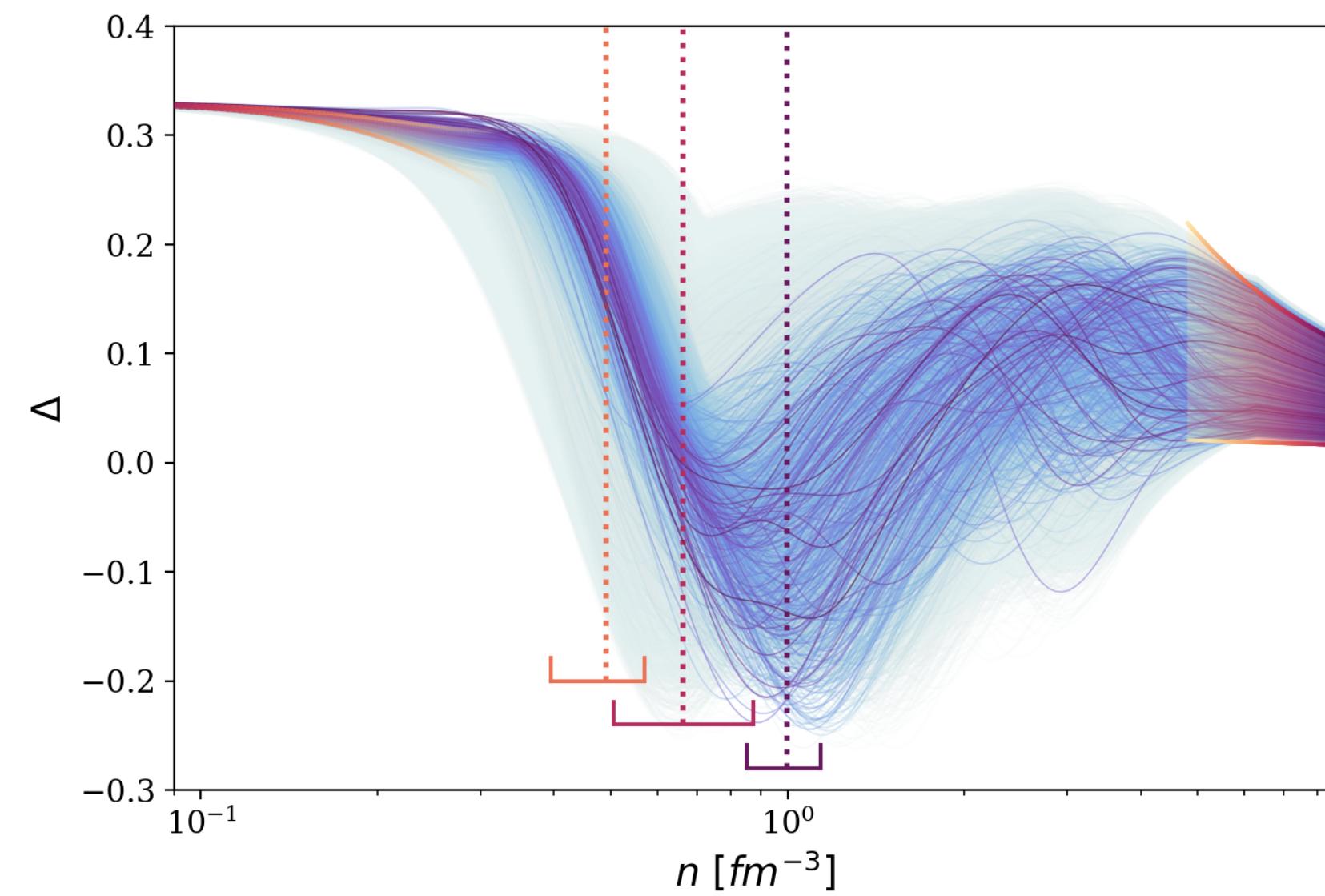
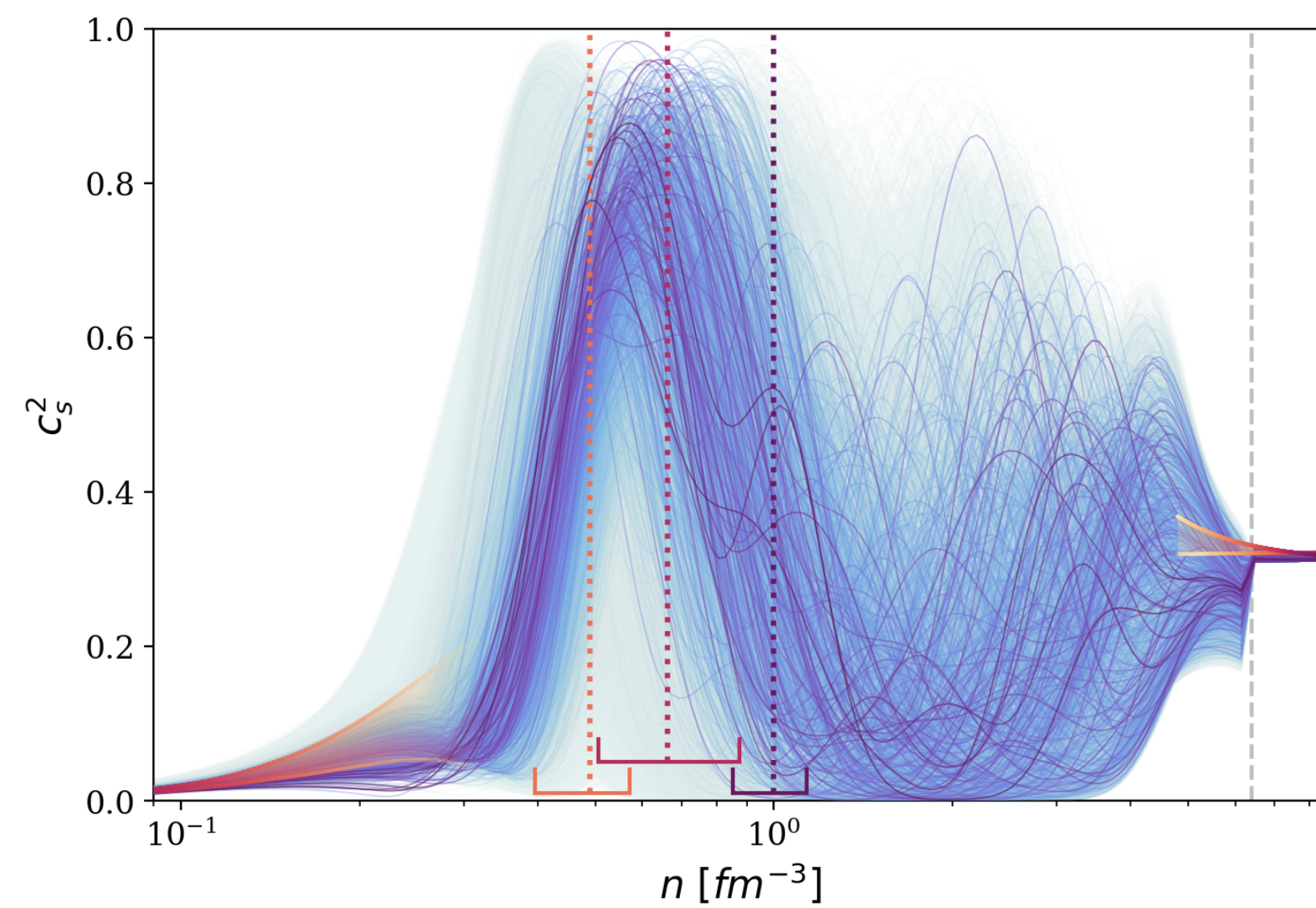
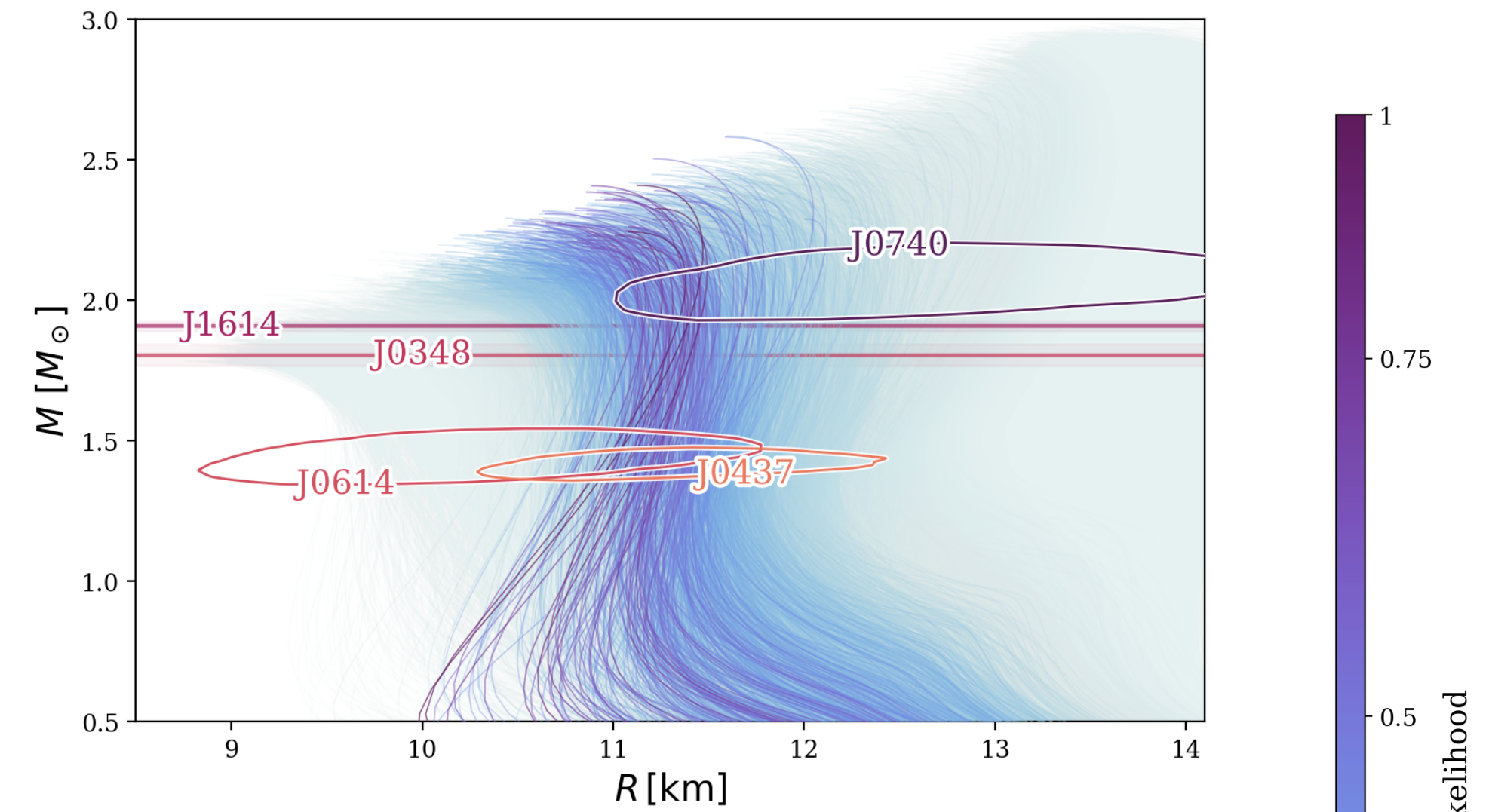
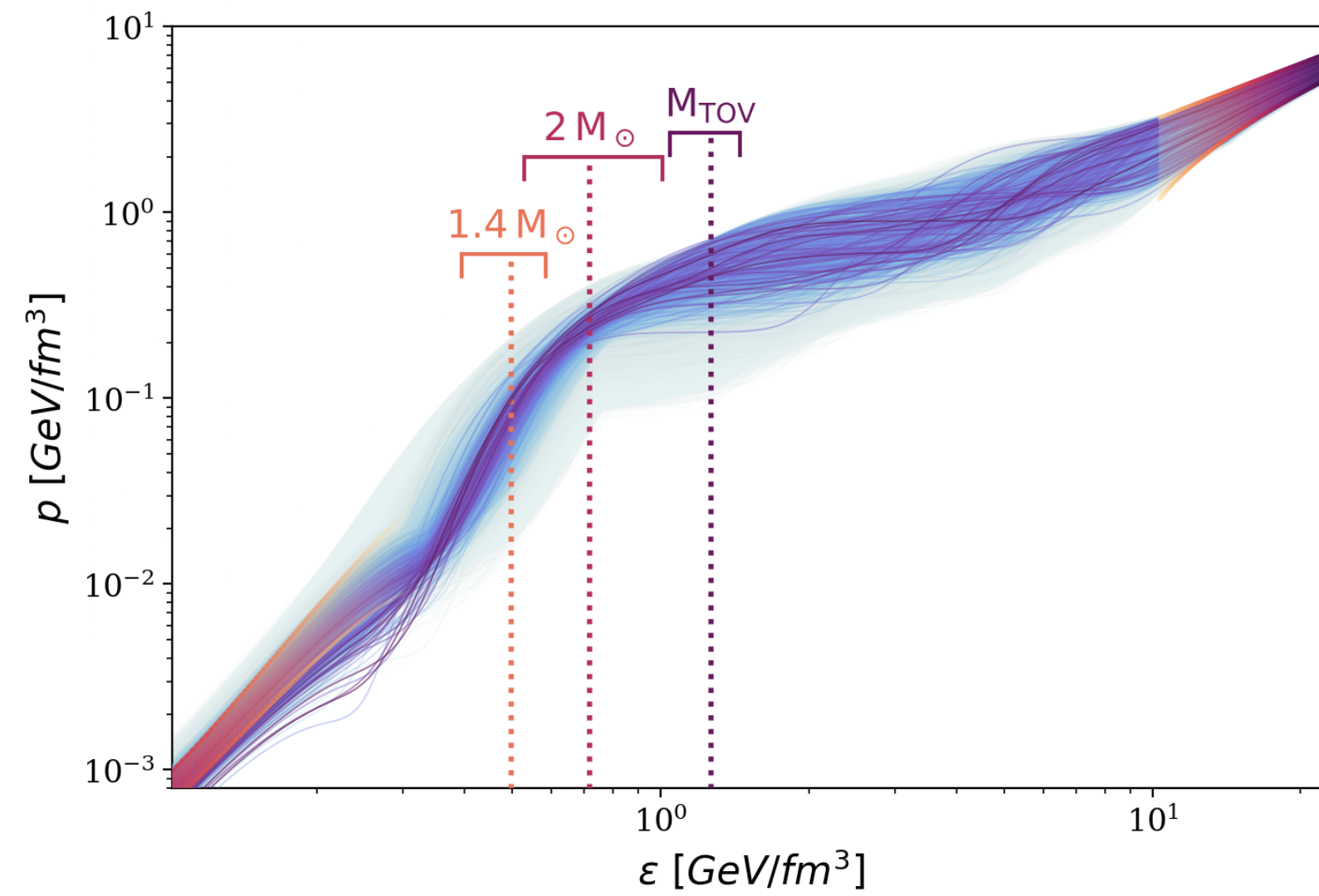


more than a mere prior

physically motivated framework



constrained Gaussian-process bridge



conclusions

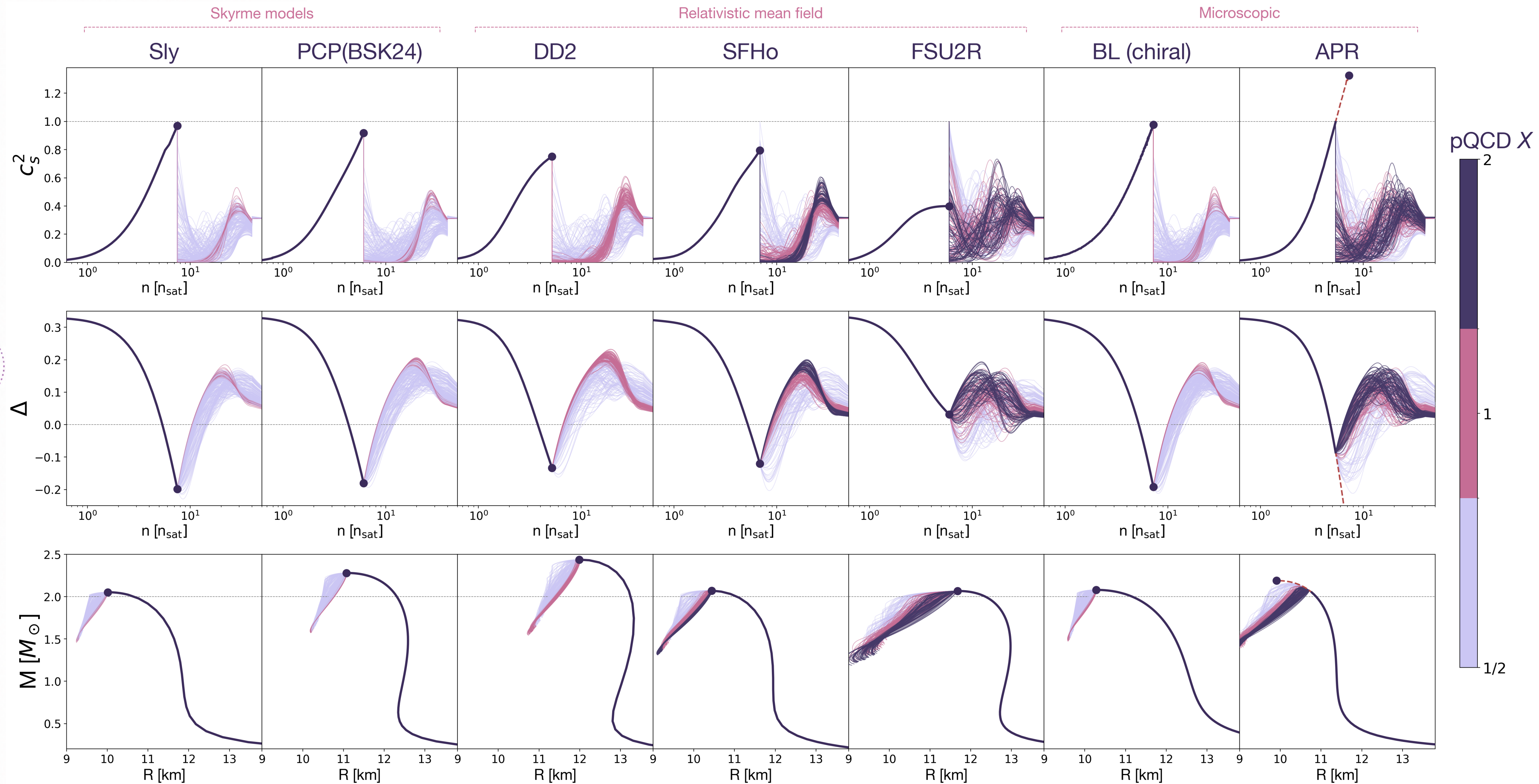
new prior for neutron-star EoS inference

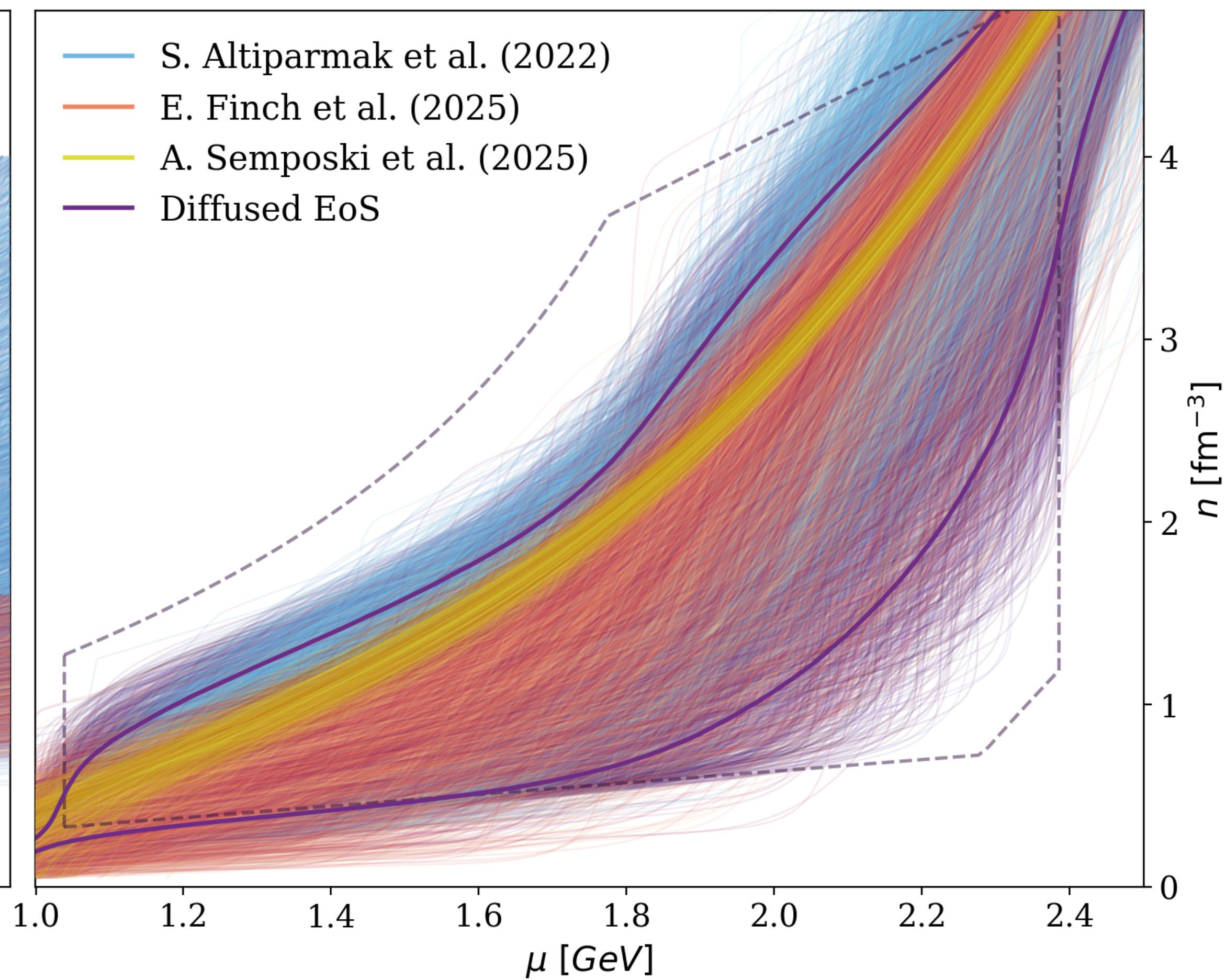
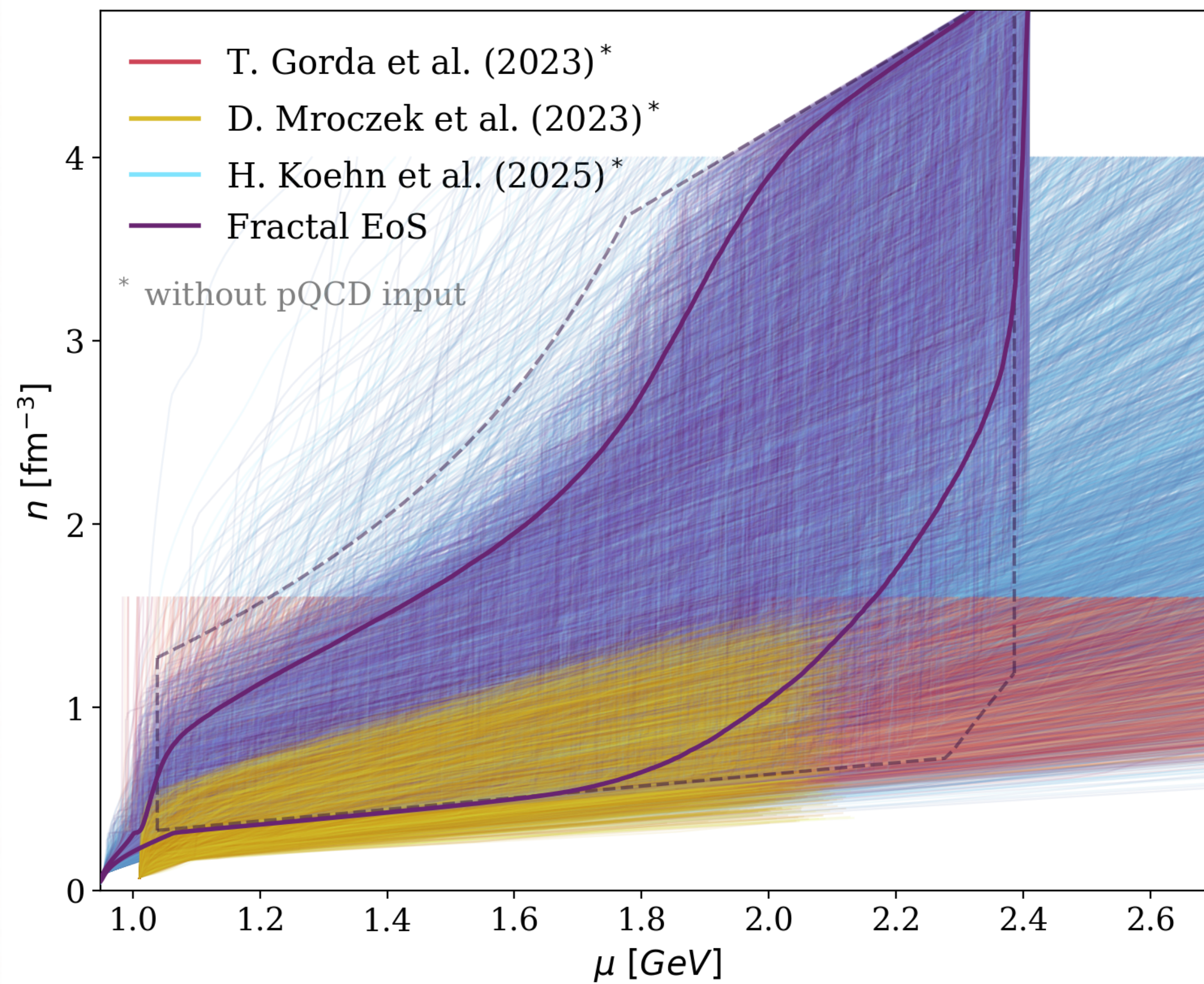
- nonparametric
- physically motivated
- maximally general
- no intermediate likelihoods
- no shooting procedure
- most efficient
- transparent tuning of correlation length

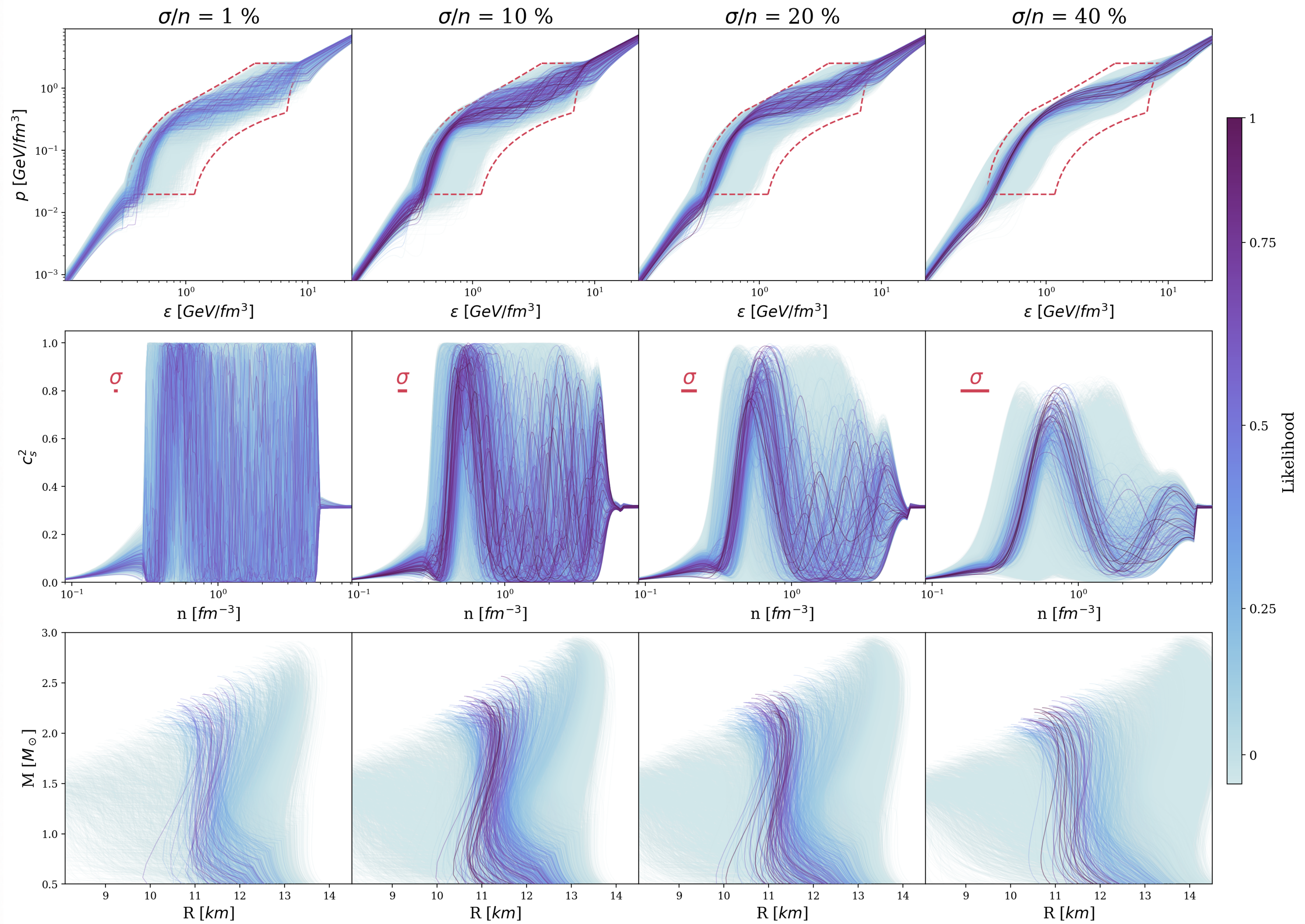
global anticorrelation in sounds speed

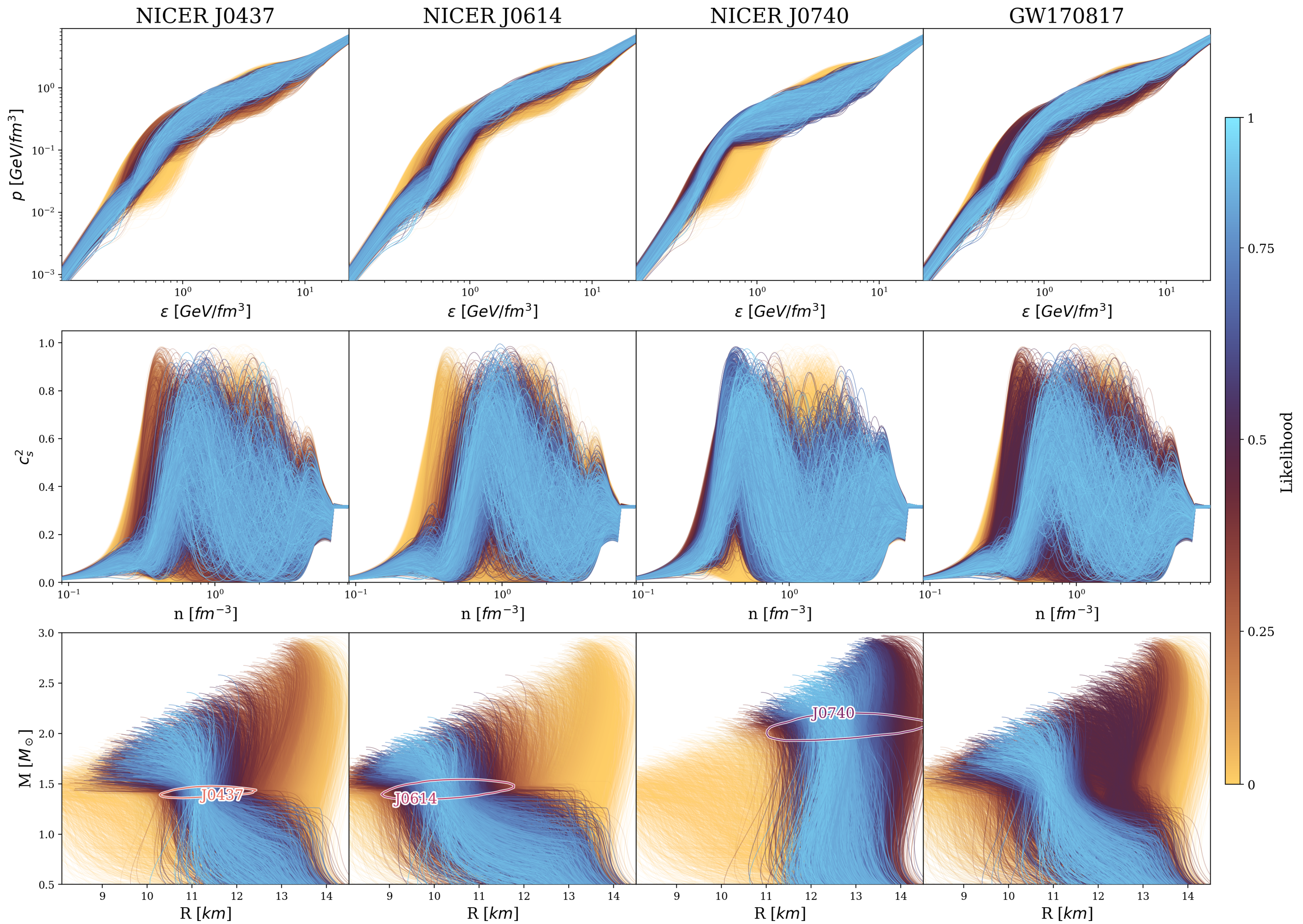
stiff EoS at intermediate densities must soften at higher density

preliminary results









introducing local Gaussian correlation

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

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 $\varepsilon' - \varepsilon = \int_n^{n'} \mu(n) dn \quad \varepsilon = -p + \mu n$

$$\partial_\tau (\varepsilon_H - \varepsilon_L) = \partial_\tau \int_{n_L}^{n_H} dn \mu(n, \tau) = [D(n) \partial_n \mu(n, \tau)]_{n_L}^{n_H}$$

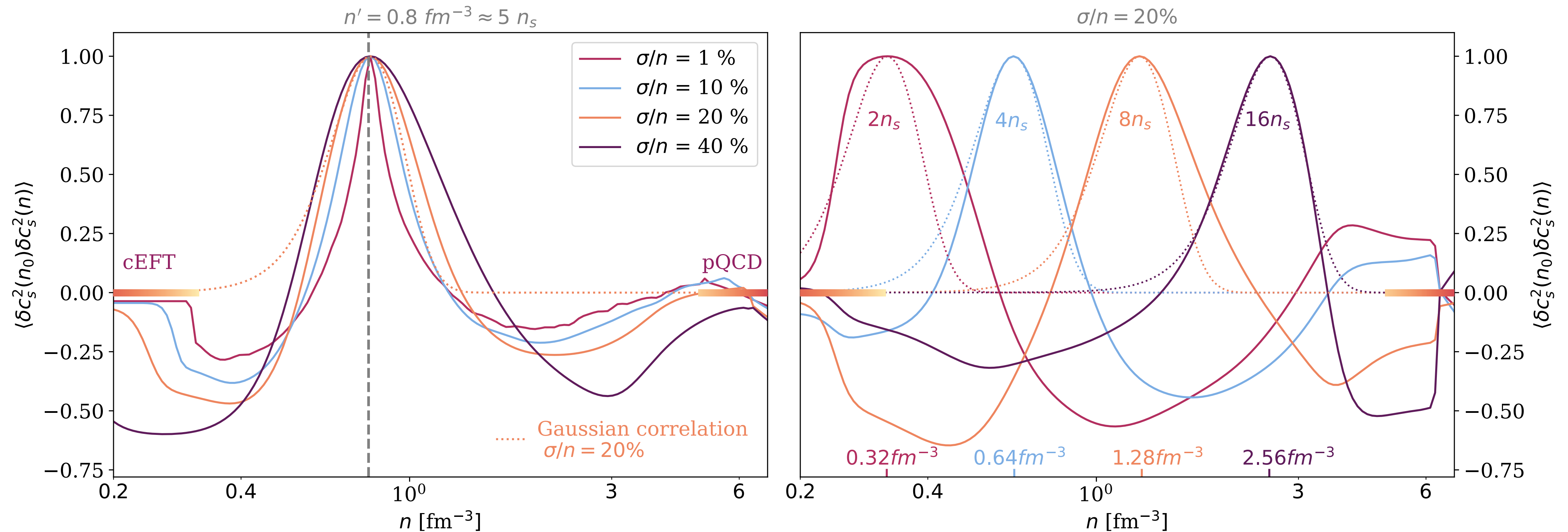
energy density may “flow” through edges

introducing local Gaussian correlation

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

logarithmically constant $\dots \sigma/n = c$

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



introducing local Gaussian correlation

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

correlation function of the sound-speed fluctuations ... $\delta c_s^2 := c_s^2 - \langle c_s^2 \rangle$

$$\langle \delta c_s^2(n, \tau) \delta c_s^2(n', \tau) \rangle = \int d\xi d\xi' G(n, \xi; \tau) G(n', \xi'; \tau) \langle \delta c_s^2(\xi, 0) \delta c_s^2(\xi', 0) \rangle \propto \frac{1}{\sqrt{8\pi D(n) \tau}} \exp \left[-\frac{(n - n')^2}{8D(n) \tau} \right]$$

$G(n, \xi; \tau)$ **Green's function of diffusion equation (locally Gaussian)**

$\langle \delta c_s^2(\xi, 0) \delta c_s^2(\xi', 0) \rangle \simeq \sigma_s^2 \delta(\xi - \xi')$ **nearly white noise initial condition**

$\langle \delta c_s^2(n, \tau) \delta c_s^2(n', \tau) \rangle$ **evolved correlation function is Gaussian**

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