Cosmology and terrestrial signals of sexaquark dark matter

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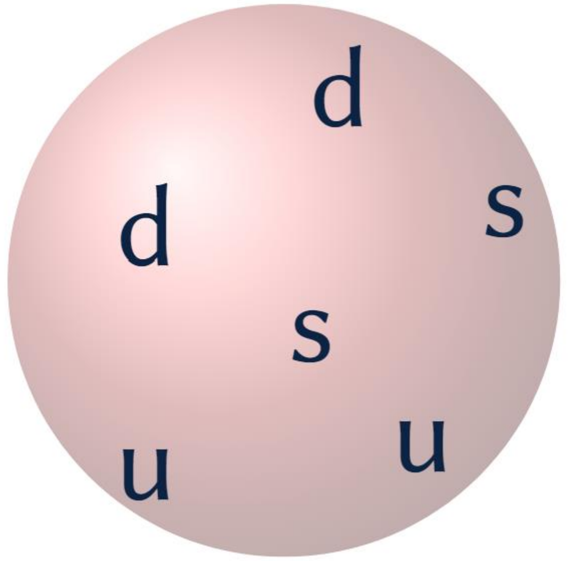
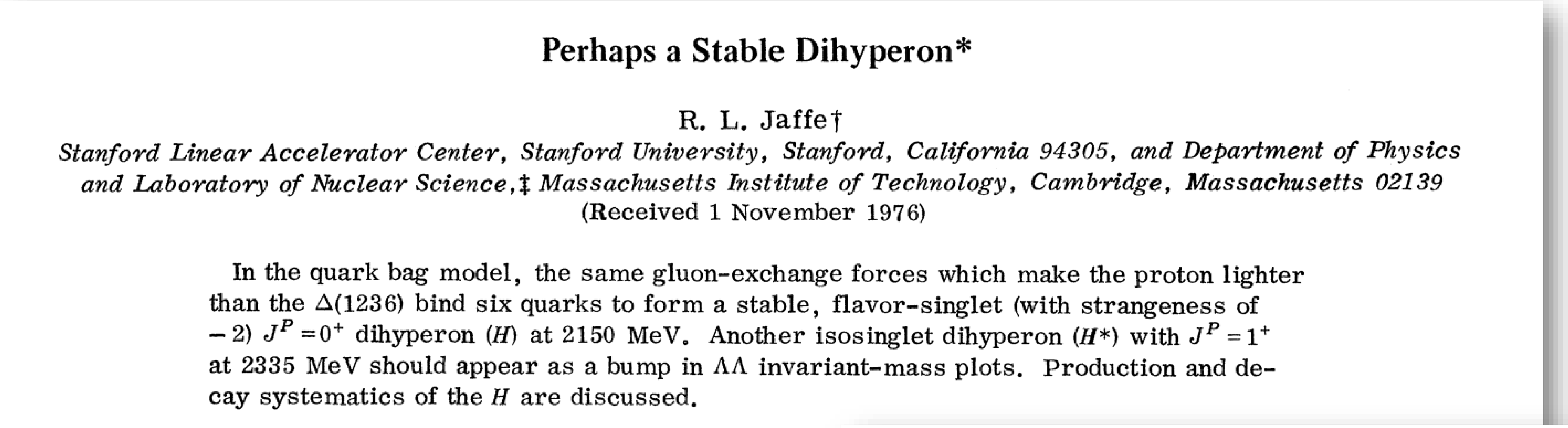
The sexaquark history





Perhaps a Stable Dihyperon*

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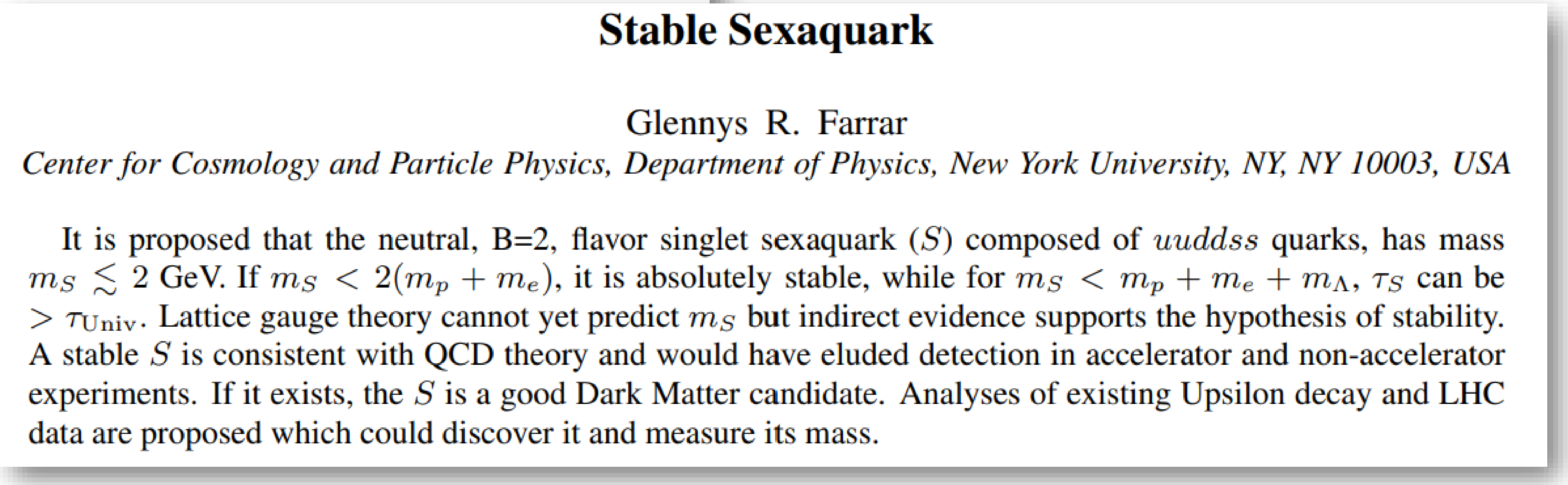
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305, and Department of Physics and Laboratory of Nuclear Science,‡ Massachusetts Institute of Technology, Cambridge, Massachusetts 02139
(Received 1 November 1976)

In the quark bag model, the same gluon-exchange forces which make the proton lighter than the $\Delta(1236)$ bind six quarks to form a stable, flavor-singlet (with strangeness of -2) $J^P=0^+$ dihyperon (H) at 2150 MeV. Another isosinglet dihyperon (H^*) with $J^P=1^+$ at 2335 MeV should appear as a bump in $\Lambda\Lambda$ invariant-mass plots. Production and decay systematics of the H are discussed.



Stable Sexaquark

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Center for Cosmology and Particle Physics, Department of Physics, New York University, NY, NY 10003, USA

It is proposed that the neutral, B=2, flavor singlet sexaquark (S) composed of $uuddss$ quarks, has mass $m_S \lesssim 2$ GeV. If $m_S < 2(m_p + m_e)$, it is absolutely stable, while for $m_S < m_p + m_e + m_\Lambda$, τ_S can be $> \tau_{\rm Univ}$. Lattice gauge theory cannot yet predict m_S but indirect evidence supports the hypothesis of stability. A stable S is consistent with QCD theory and would have eluded detection in accelerator and non-accelerator experiments. If it exists, the S is a good Dark Matter candidate. Analyses of existing Upsilon decay and LHC data are proposed which could discover it and measure its mass.

no net spin nor charge
stable for $1860 \leq m_S \leq 1890$ MeV

Can the sexaquark constitute *all* of dark matter?

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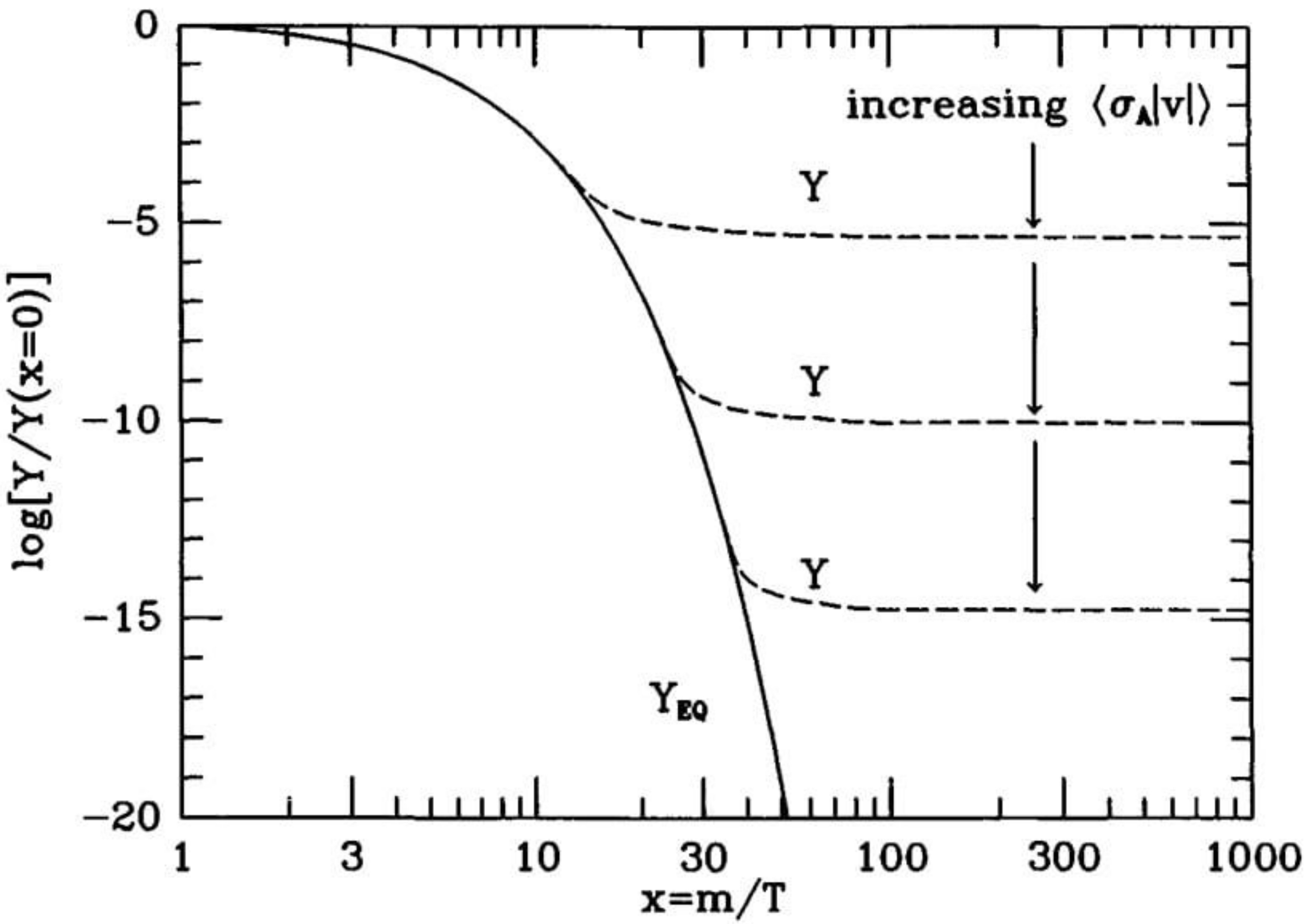
If not, what fraction could it consistently make up?

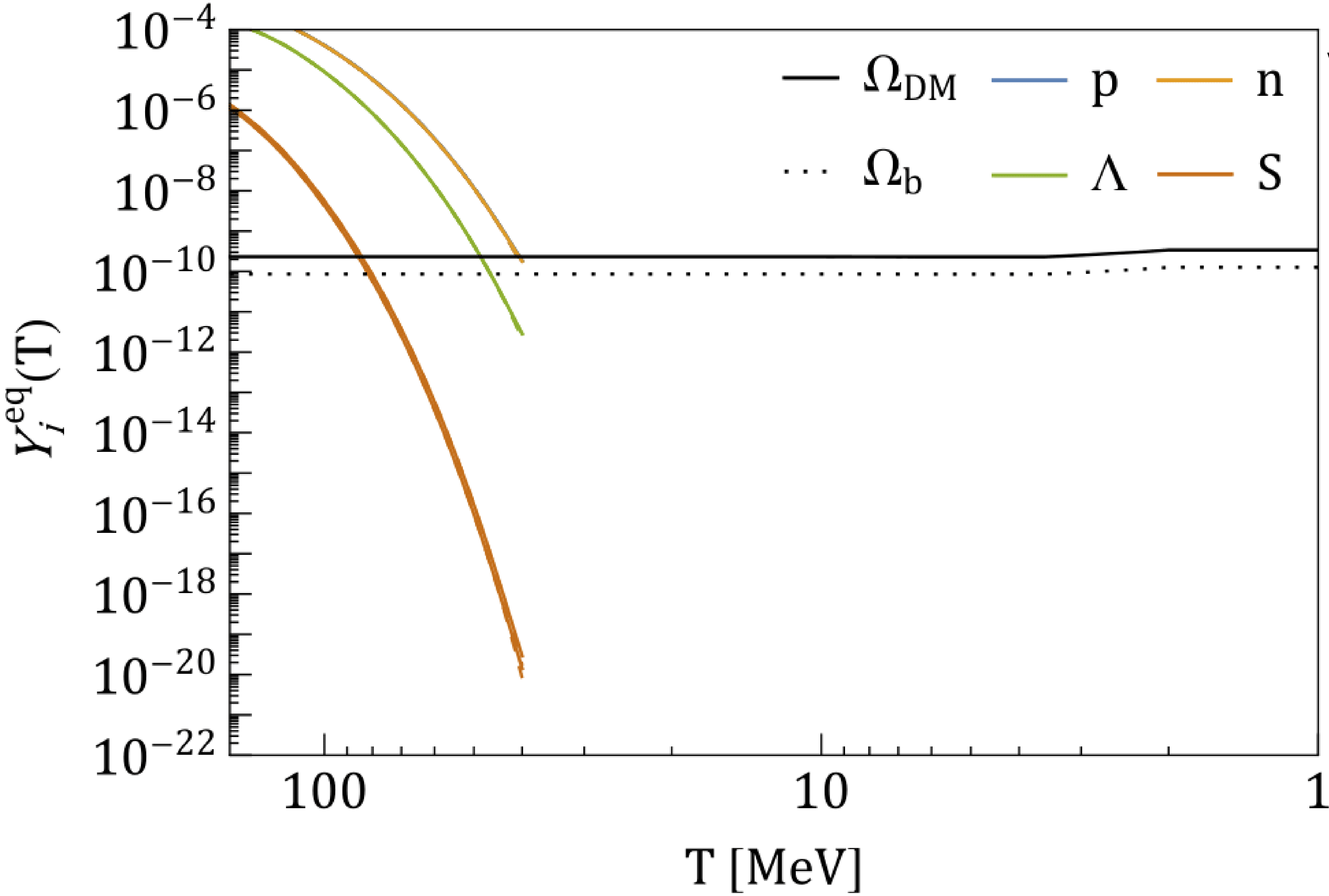
Freeze-out of WIMPs



no chemical potential

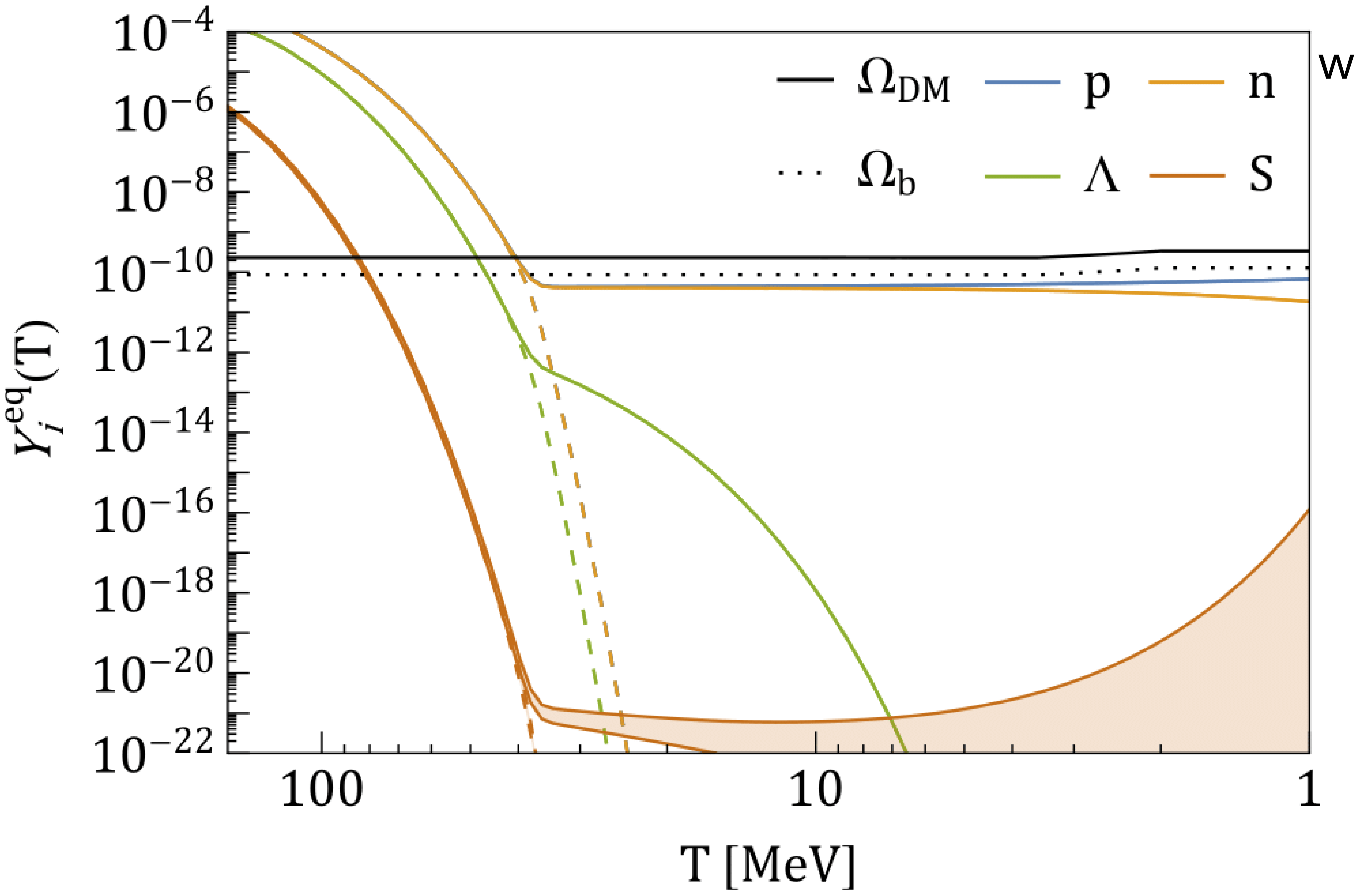
Kolb and Turner

Equilibrium abundance of the sexaquark



with chemical potential

Equilibrium abundance of the sexaquark



with chemical potential

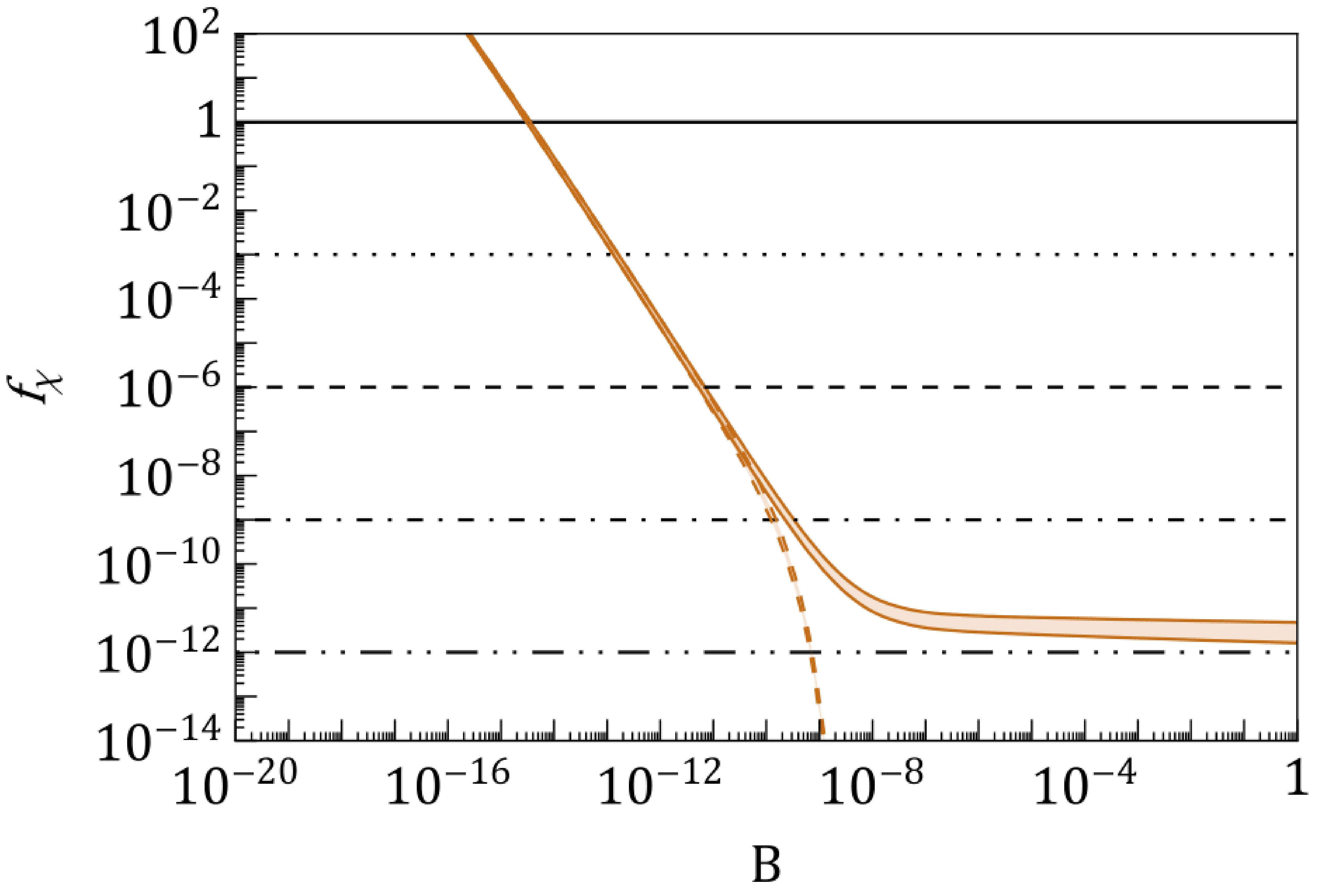
Freeze-out of the sexaquark

Three main processes can lead to freeze-out

$$S\bar{S} \to \text{SM particles}$$

$$\left.\begin{aligned} S\pi &\to bb' \\ S\bar{b} &\to b'\pi \end{aligned}\right\} \qquad \propto B m_\pi^{-2},\ \text{with } B \leq 1$$

Freeze-out of the sexaquark



To account for *all* of dark matter:

- Sexaquarks must depart from equilibrium at early times
- At the expanse of also producing antisexaquarks
- Requires strongly suppressed cross sections (small B’s)

Annihilation signals

- **Directly in a detector**
  (e.g. 2303.03416)
- In the Earth core, producing
  - anomalous heating
    (e.g. 0705.4298, 1909.11683)
  - neutrinos reaching a near-surface detector
    (e.g. 2309.10032)

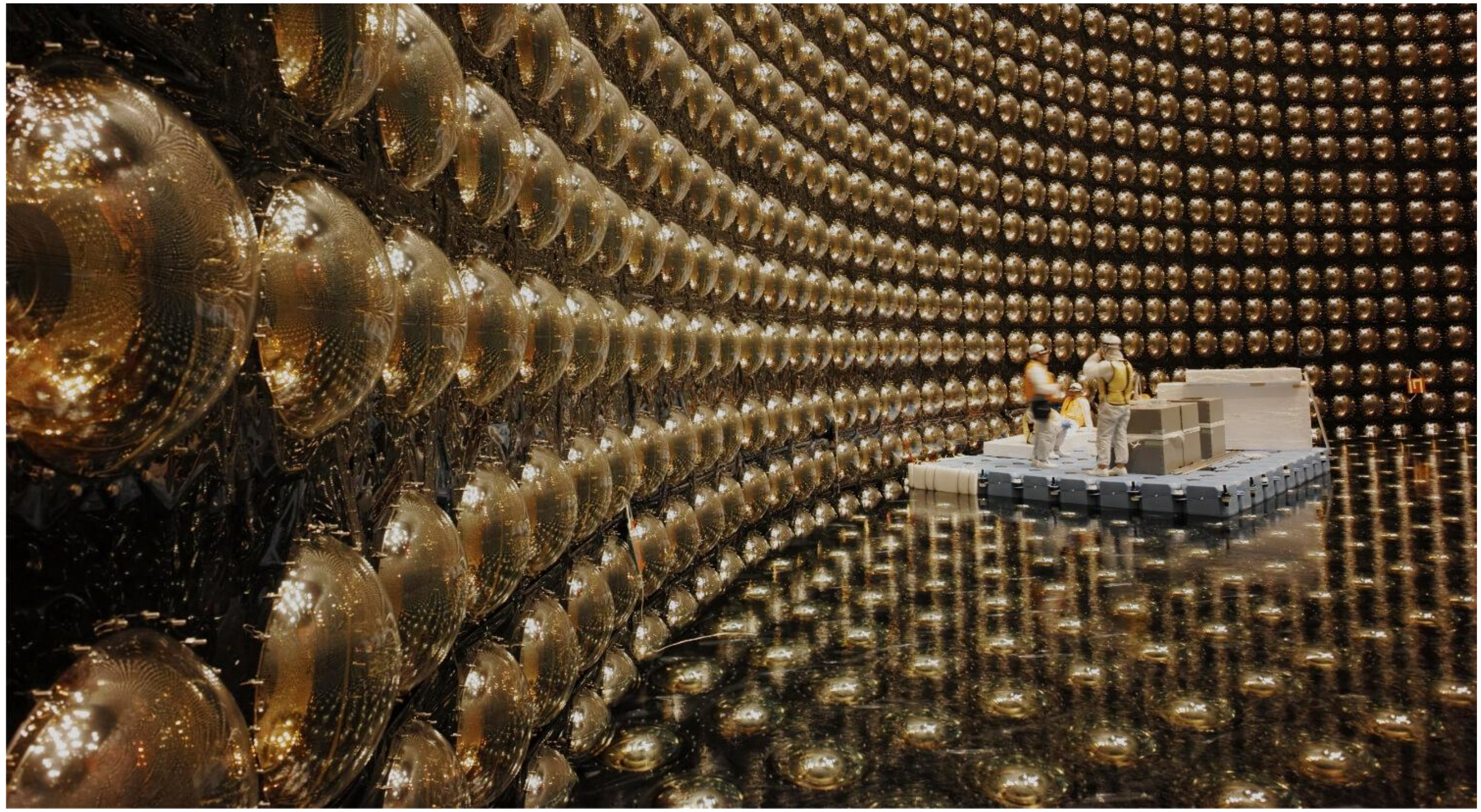
Scattering signals

- Standard direct detection
  e.g. in CRESST-III, DarkSide-20k
  unless $\sigma_{\chi n}$ is too large
- Upscattered to a test detector
  (e.g. MM+ 2202.08840)

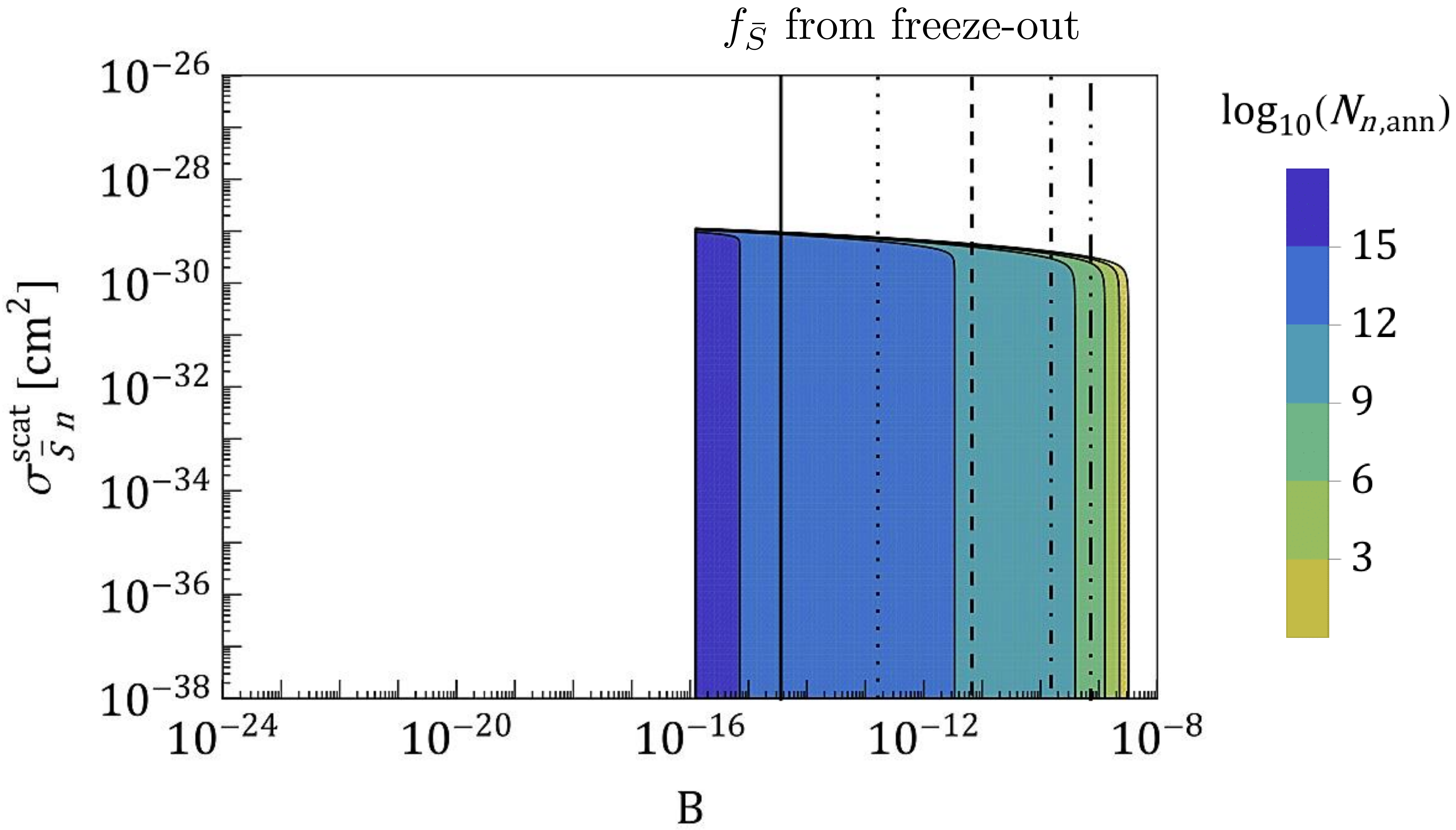
Annihilation in Super-Kamiokande

Why Super-Kamiokande?

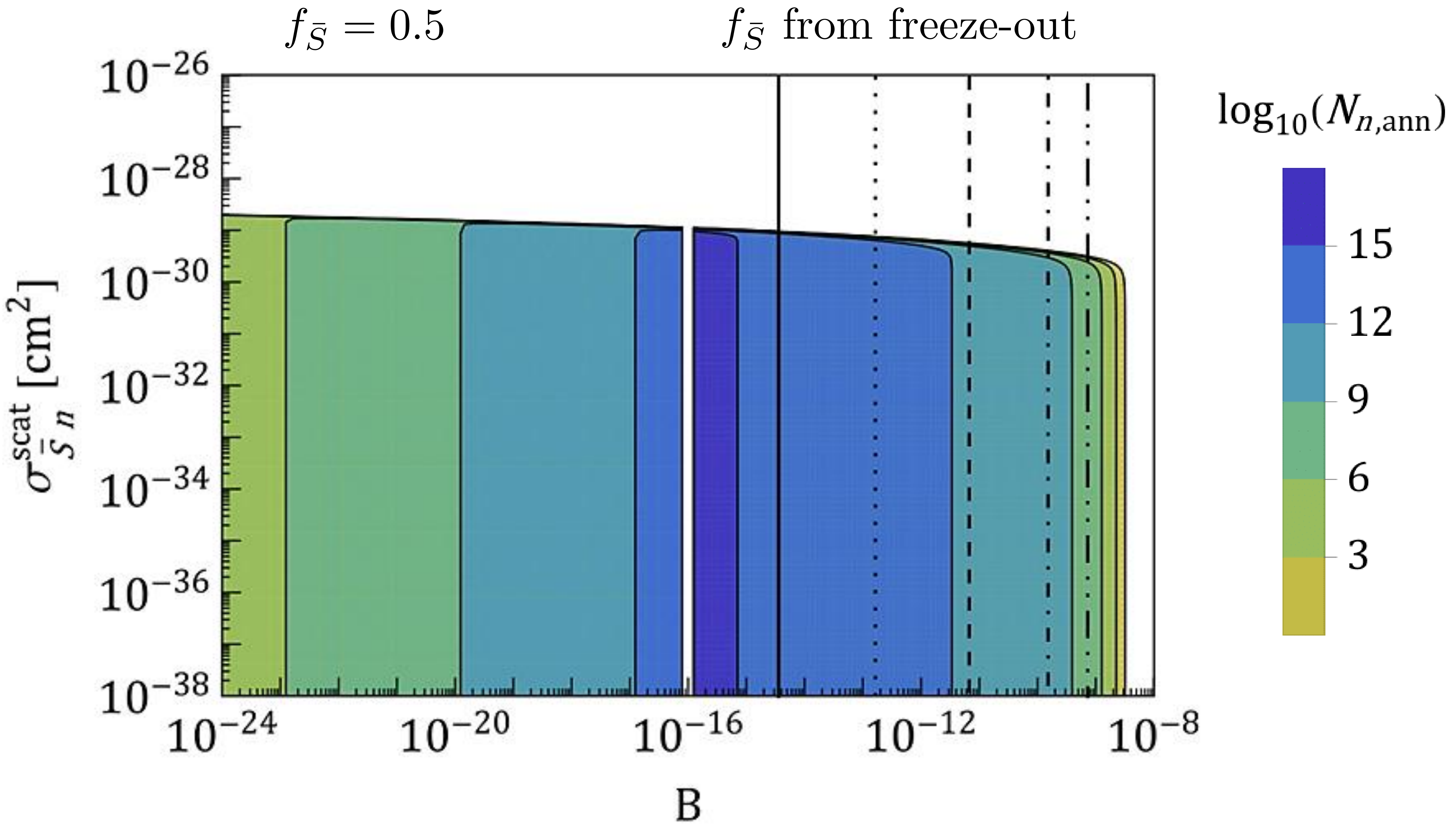
- large running time
- large volume
- easy to distinguish annihilation signature (invariant mass, momentum)
- same cuts as $n-\bar{n}$ oscillations and nucleon decay



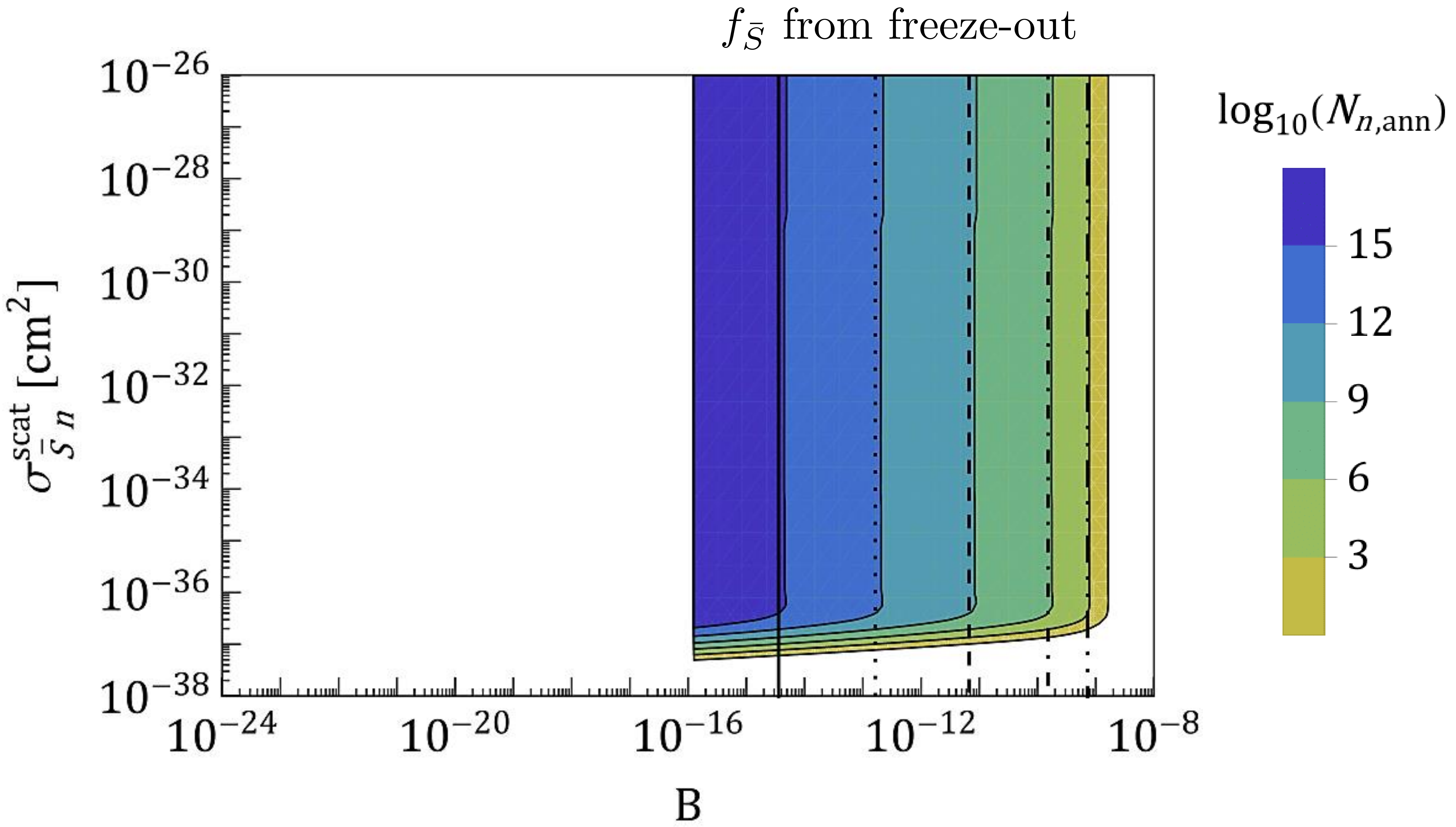
Annihilation in Super-Kamiokande (wind)



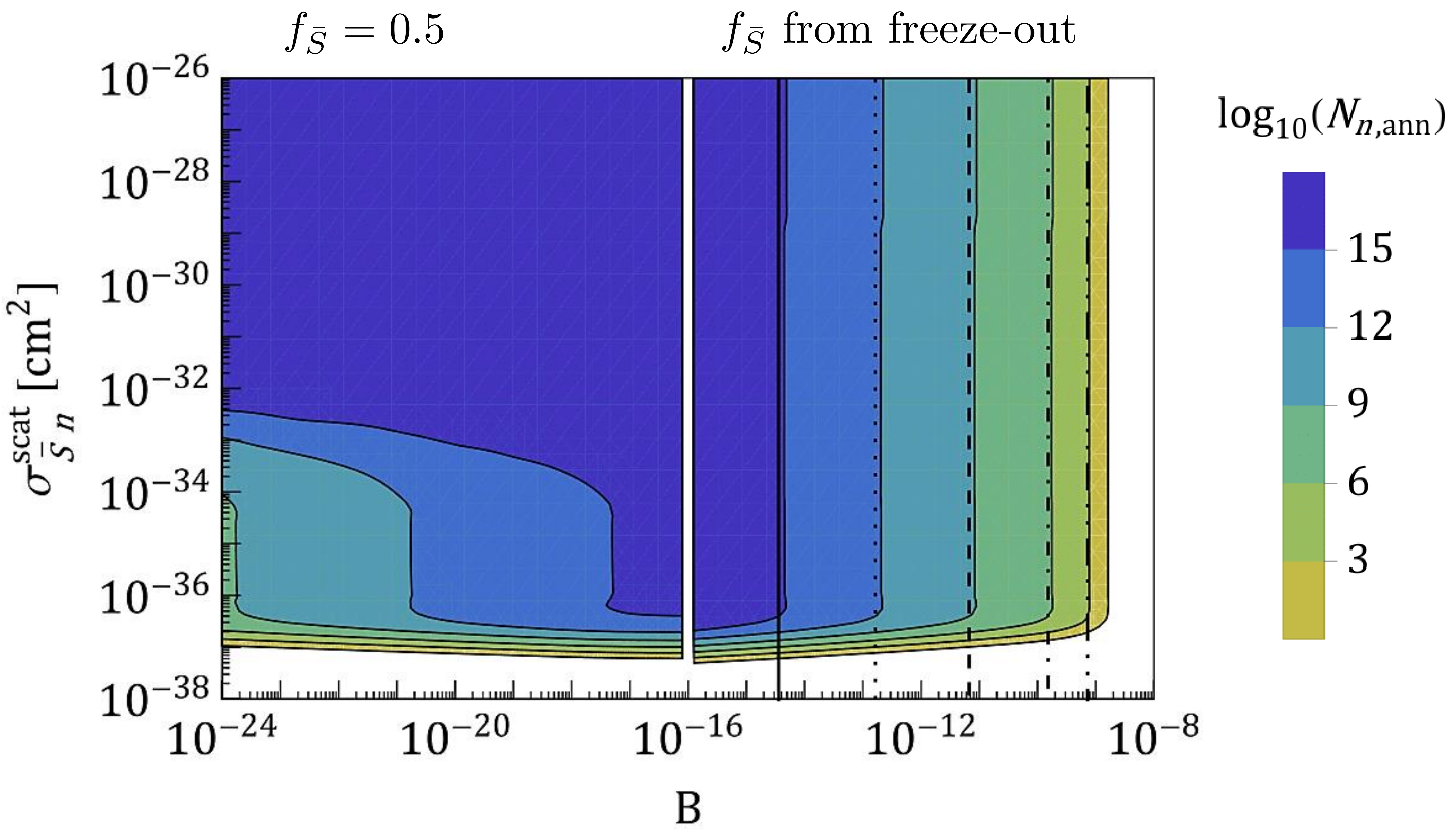
Annihilation in Super-Kamiokande (wind)



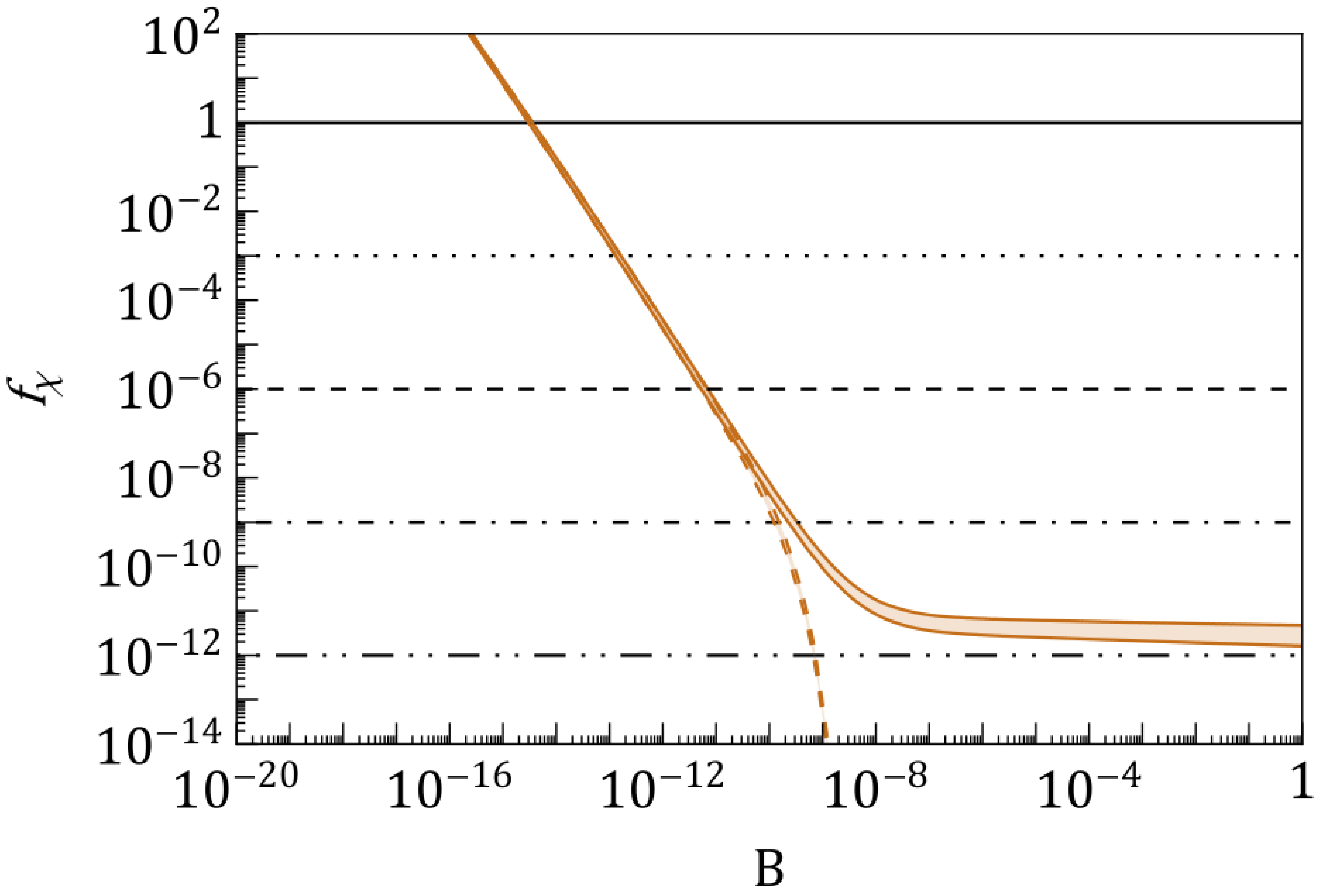
Annihilation in Super-Kamiokande (accumulated)



Annihilation in Super-Kamiokande (accumulated)



Summary


f_χ
10^2
1
10^{-2}
10^{-4}
10^{-6}
10^{-8}
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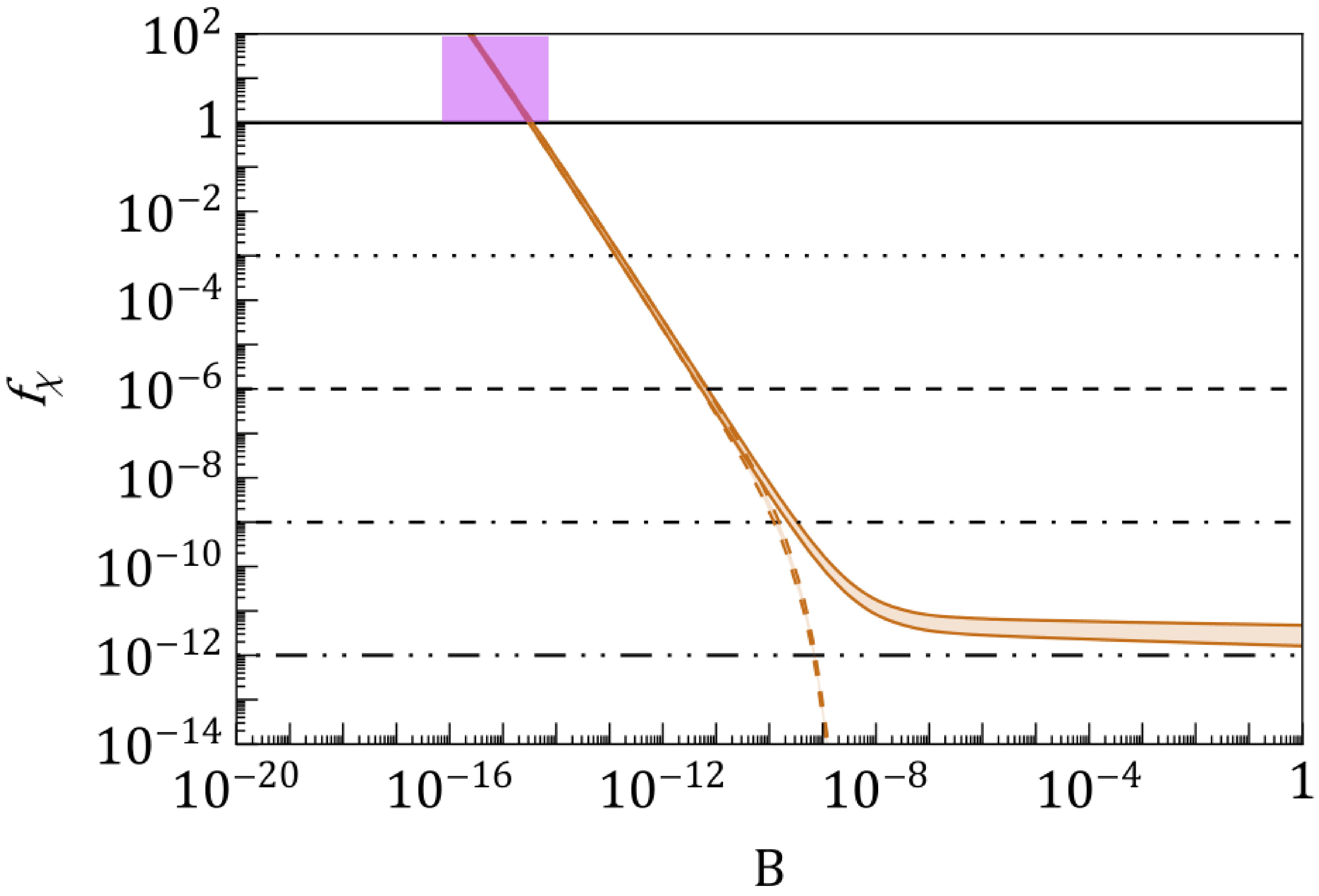
1
B

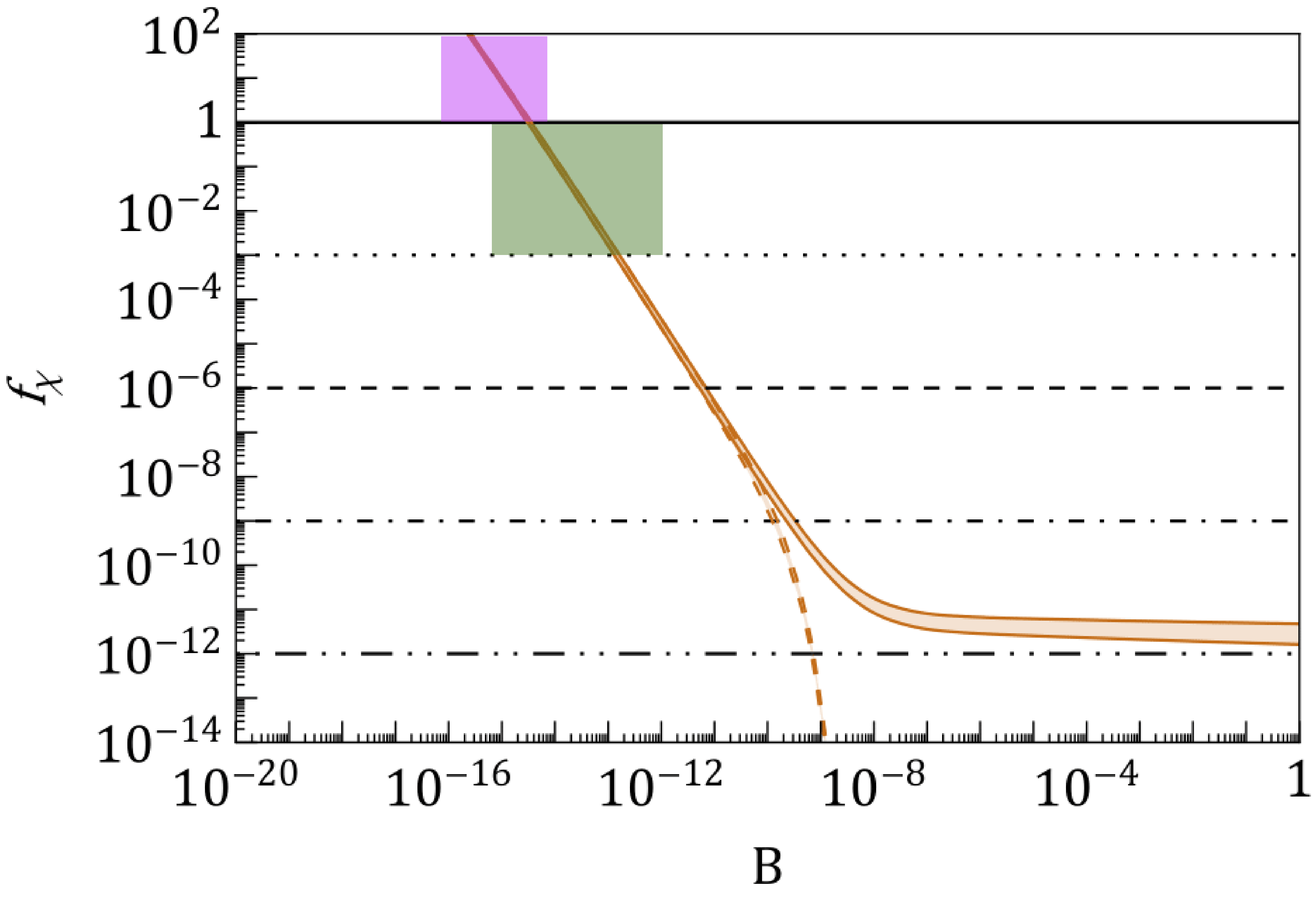
Summary



ruled out

by cosmology

Summary

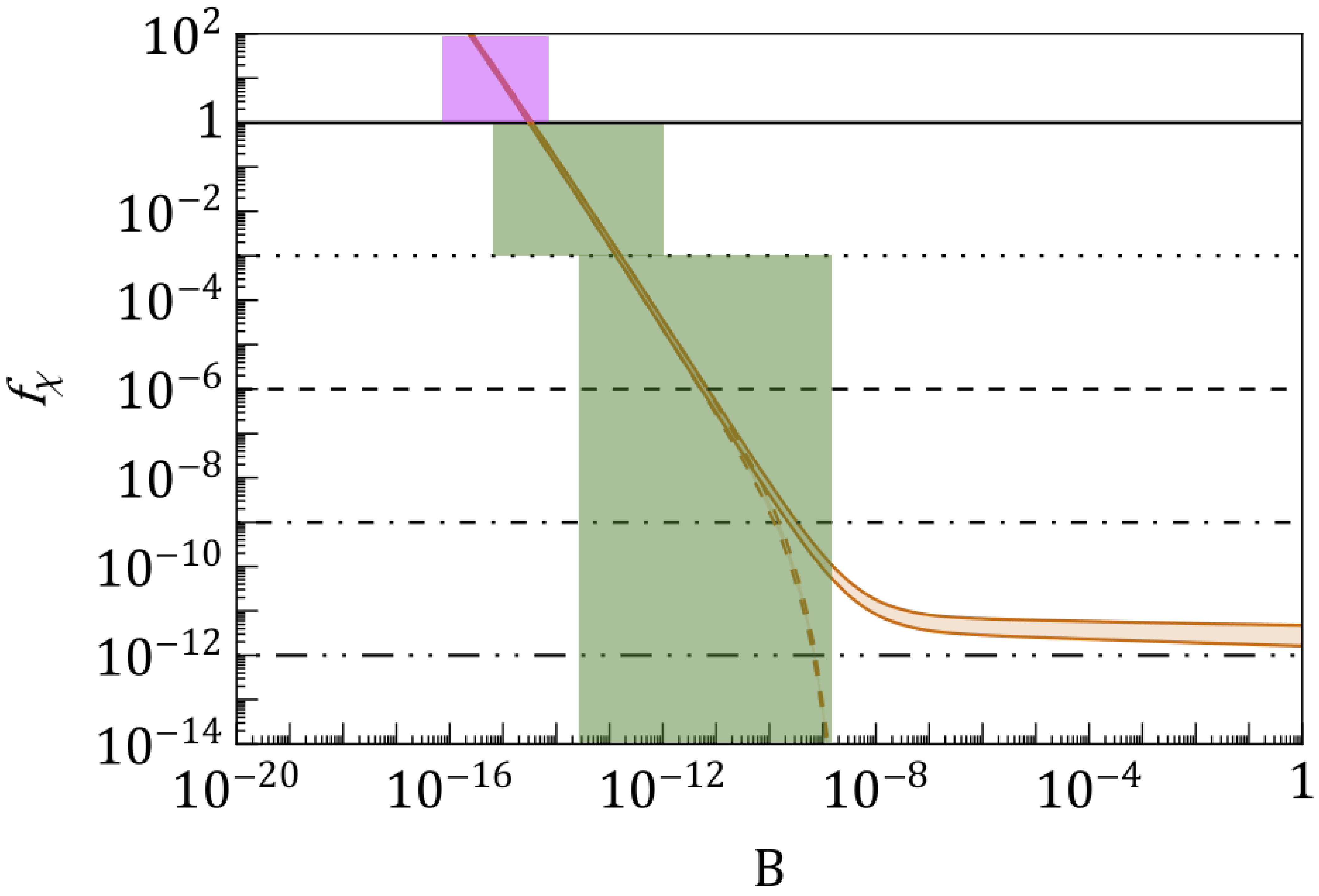


ruled out

by cosmology

by direct detection

Summary



ruled out

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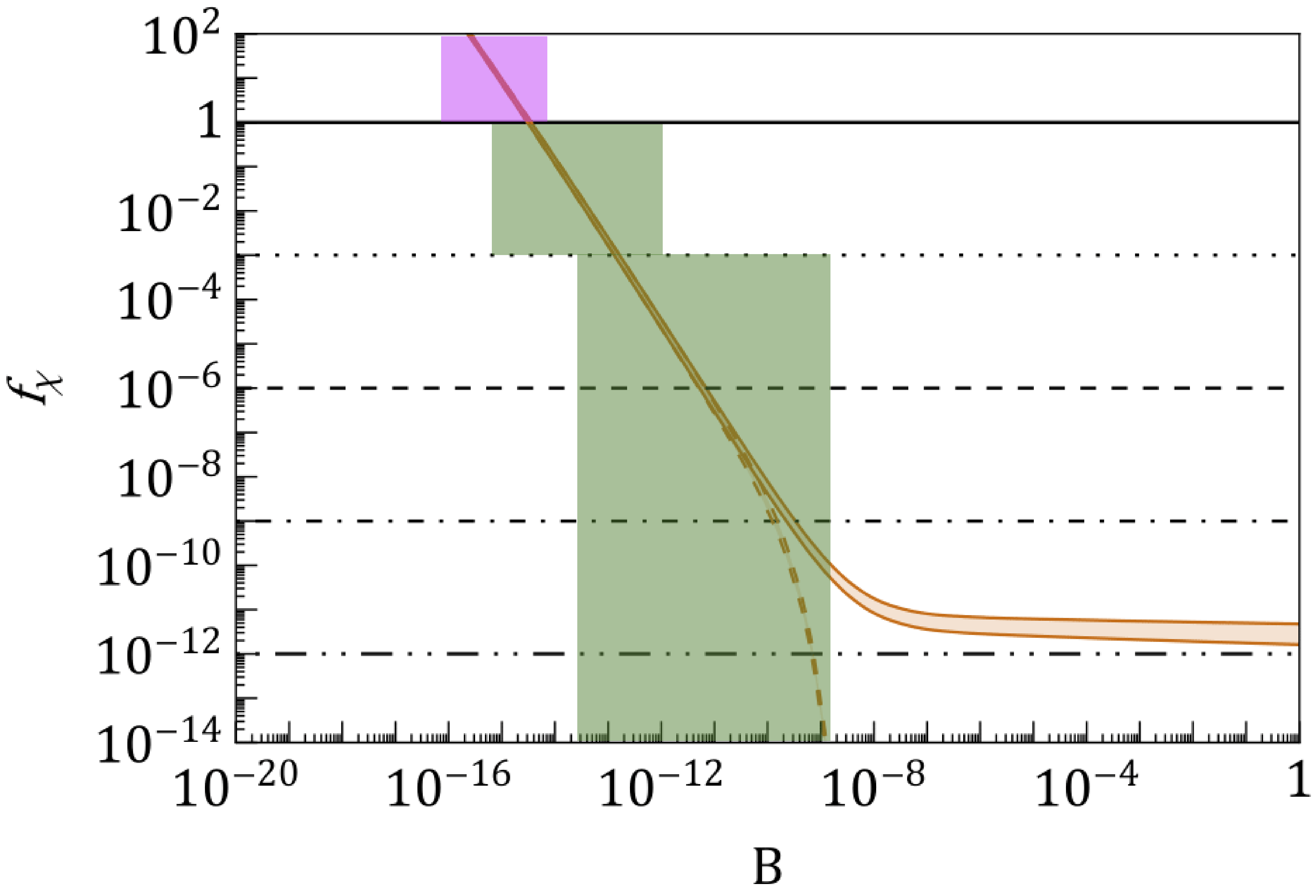

ruled out

by cosmology

by direct detection

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← likely the only option for survival