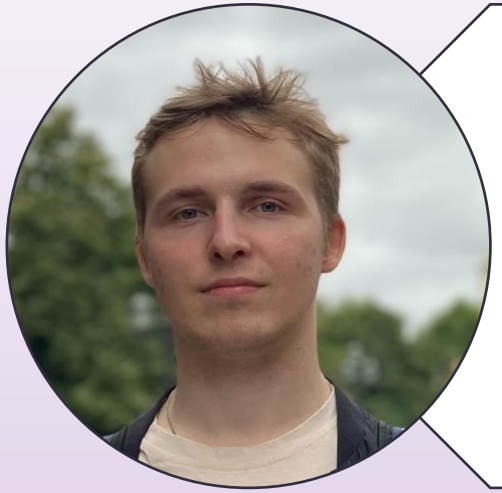
Energy-dependent flavor ratios, cascade/track spectrum tension and high-energy neutrinos from magnetospheres of supermassive black holes



Riabtsev Kirill

Lomonosov MSU, INR, Moscow

Email: riabtcev.ki19@physics.msu.ru

Phone number: +79097390829 (Telegram)

Sergey Troitsky

INR, Moscow

Intro

arXiv:2204.09339

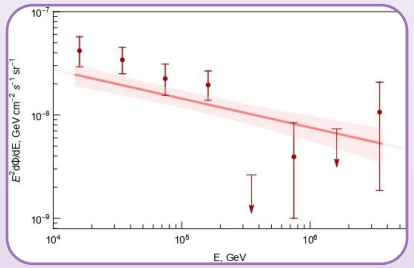
The origin of high-energy astrophysical neutrinos?

change of the flavor content of astrophysical neutrinos with energy?

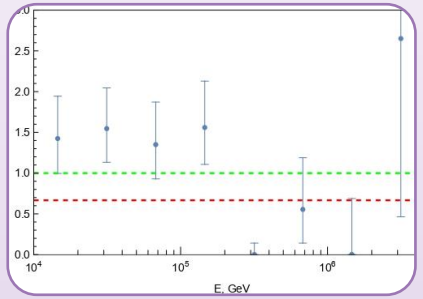
a mild tension between spectra obtained in different analyses

IceCube neutrinos (E>10000 GeV)

Analysis



Observed spectra



Flavor ratios (at the detector and at the source, taking into account neutrino oscillations)

pp-interactions:

$p + p \rightarrow \; p + p + many \times (\pi^+ + \pi^- + \pi^0)$

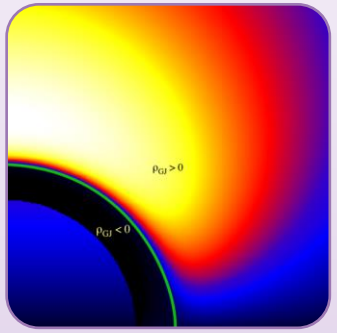
$p\gamma$-interactions:

1. $p + \gamma \rightarrow \Delta^+$
2. $\Delta^+ \rightarrow \; n + \pi^+$ or $\Delta^+ \rightarrow \; p + \pi^0$.

Decays following *pp*- and $p\gamma$-interactions:

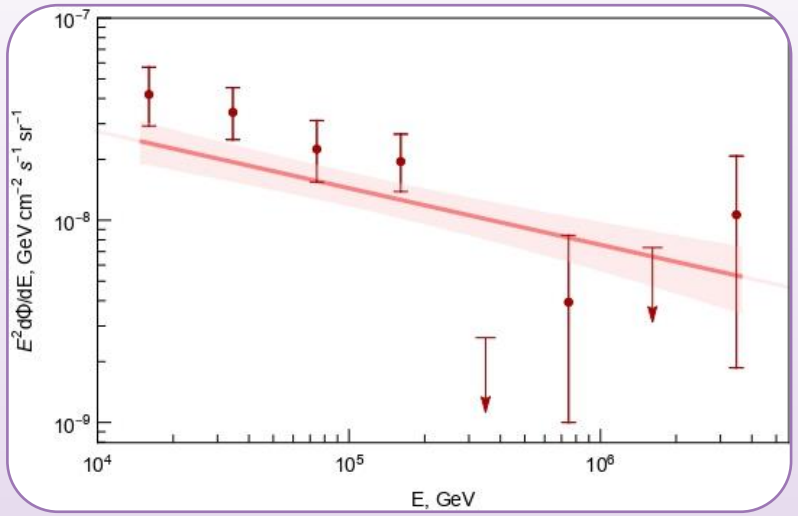
1. $\pi^0 \rightarrow \gamma + \gamma$, $\pi^\pm \rightarrow \mu^\pm + \nu_\mu\,(\overline{\nu_\mu})$
2. $\mu^\pm \rightarrow \; e^\pm + \nu_e\,(\overline{\nu_e}) + \overline{\nu_u}\,(\nu_u)$.

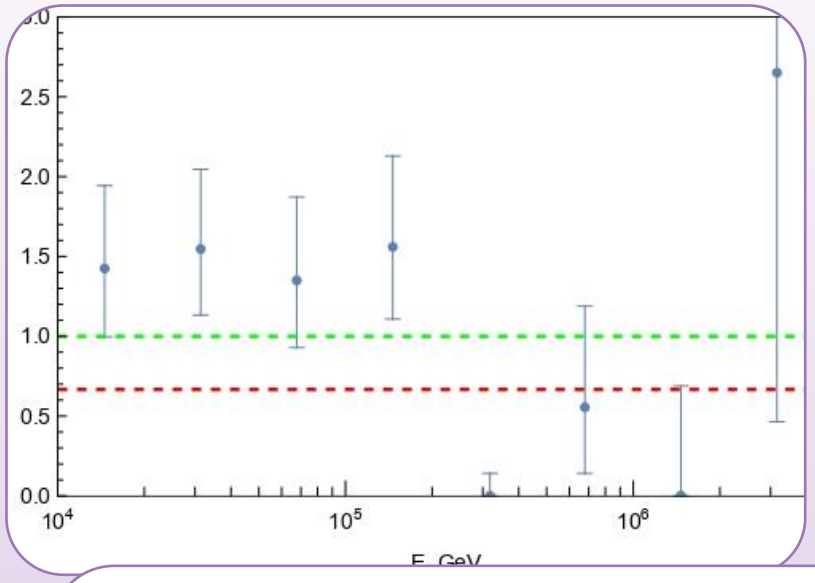
Physical conditions at the sources



The class of the sources

Analysis





Observed

spectra

- Tau plus electron neutrinos (dots with error bars)
- Mu neutrinos (solid line)

Flavor ratios (at the detector and at the source, taking into account neutrino oscillations)

- The case of flavor equipartition (dashed green line)
- The case of muon damp(dashed red line)

Analysis

pp-interactions:

$$p + p \rightarrow p + p + many \times (\pi^+ + \pi^- + \pi^0)$$

- $p\gamma$-interactions:

1. $p + \gamma \rightarrow \Delta^+$
2. $\Delta^+ \rightarrow n + \pi^+$ or $\Delta^+ \rightarrow p + \pi^0$.

- Decays following pp- and $p\gamma$-interactions:

1. $\pi^0 \rightarrow \gamma + \gamma$, $\pi^\pm \rightarrow \mu^\pm + \nu_\mu\,(\overline{\nu_\mu})$
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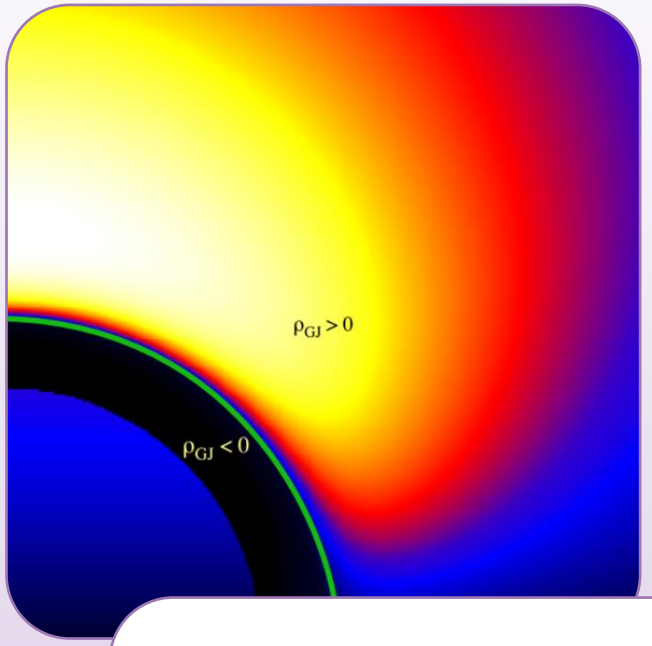


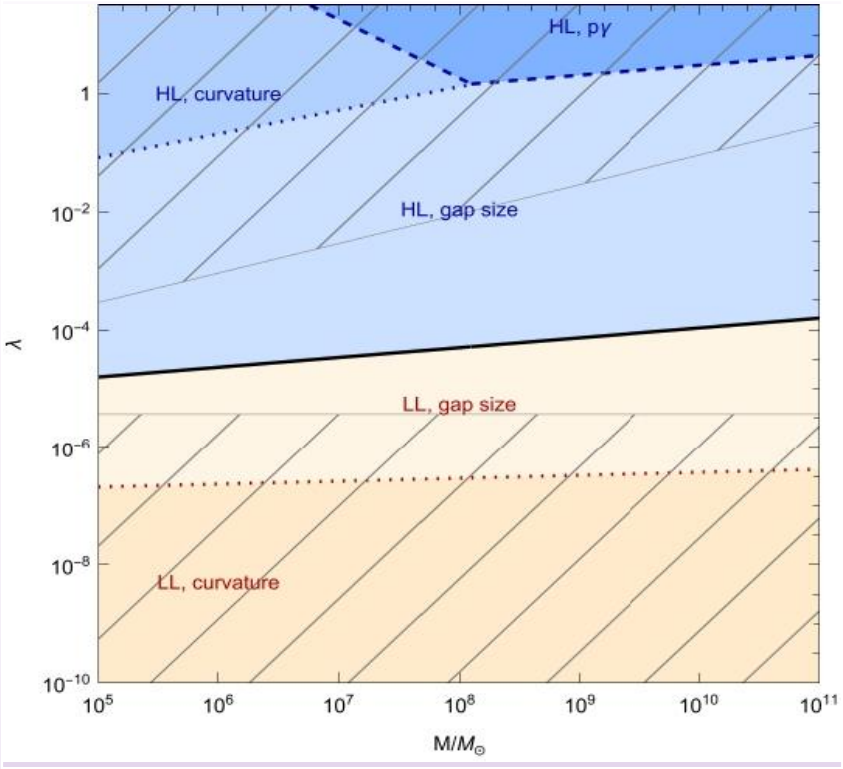
Physical conditions at the sources

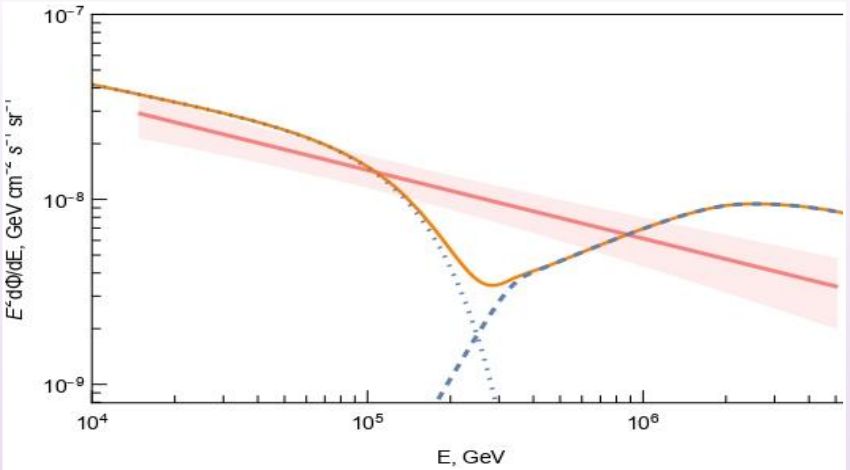
- In the case of damped muons the neutrinos from the last equation are “missing”, changings the flavor ratios
- “Muon damp” corresponds to specific magnetic fields

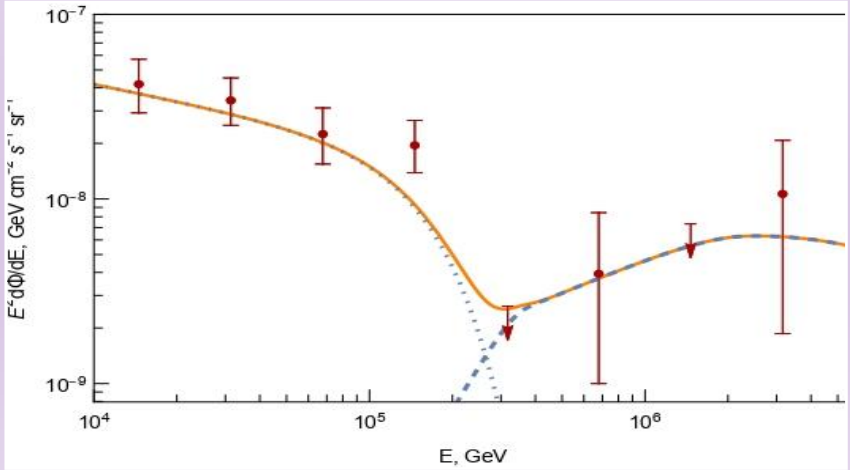
The class of the sources

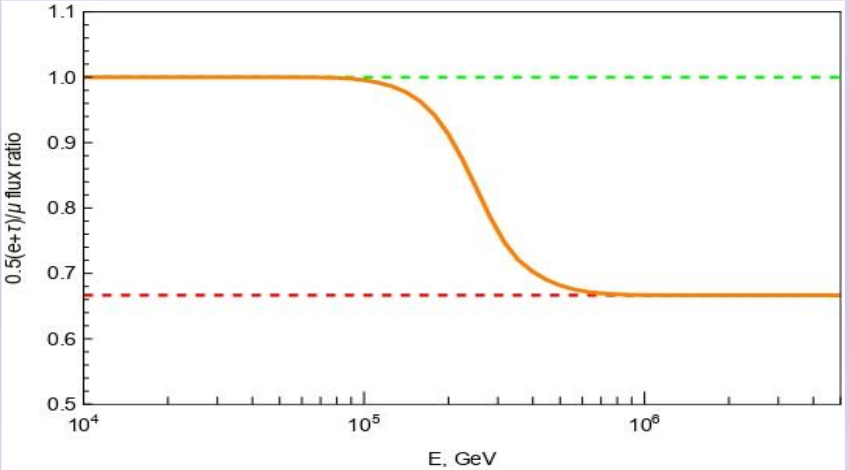
- Black holes
- ~~Gamma-ray bursts~~

SMBH toy model

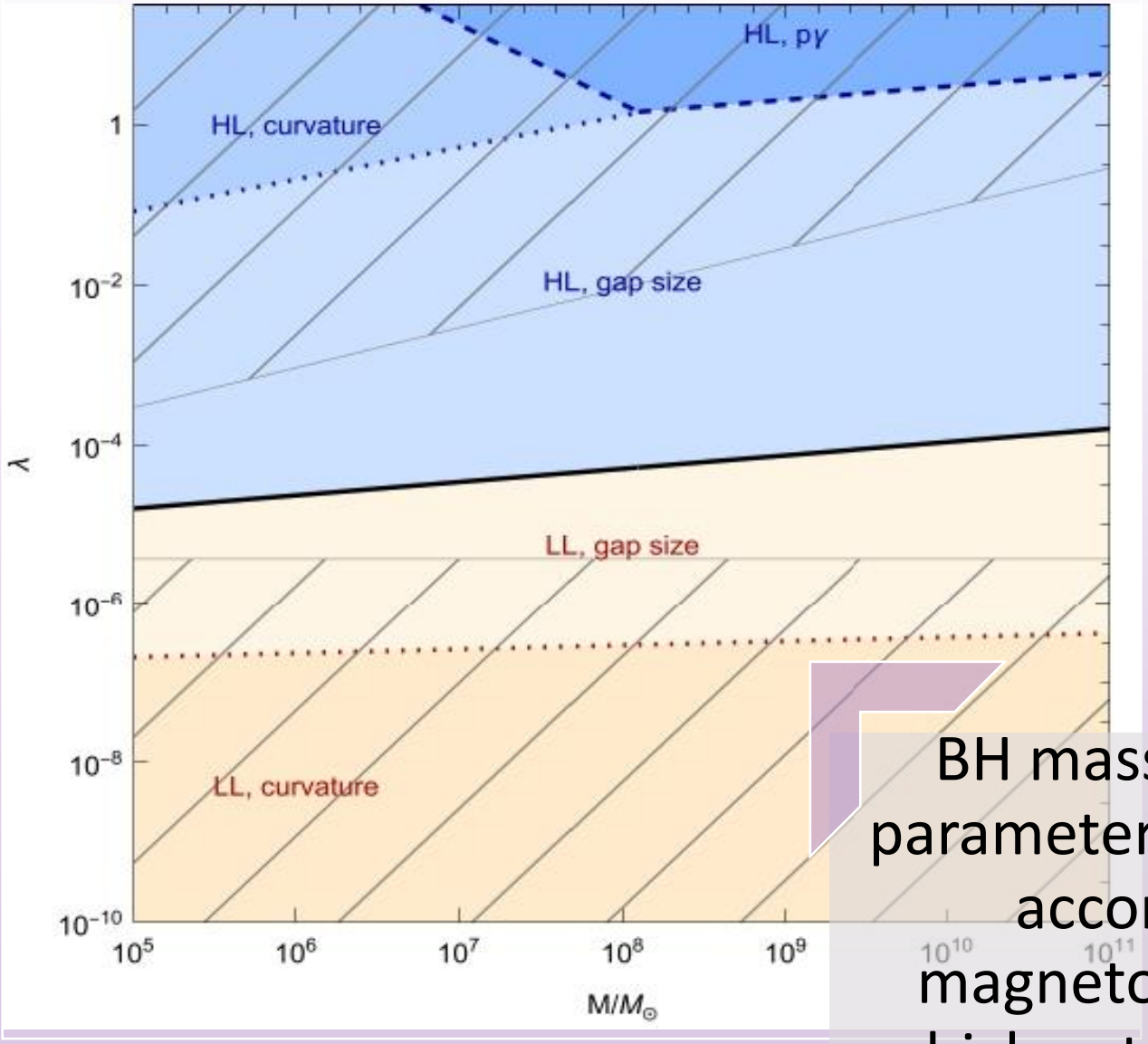






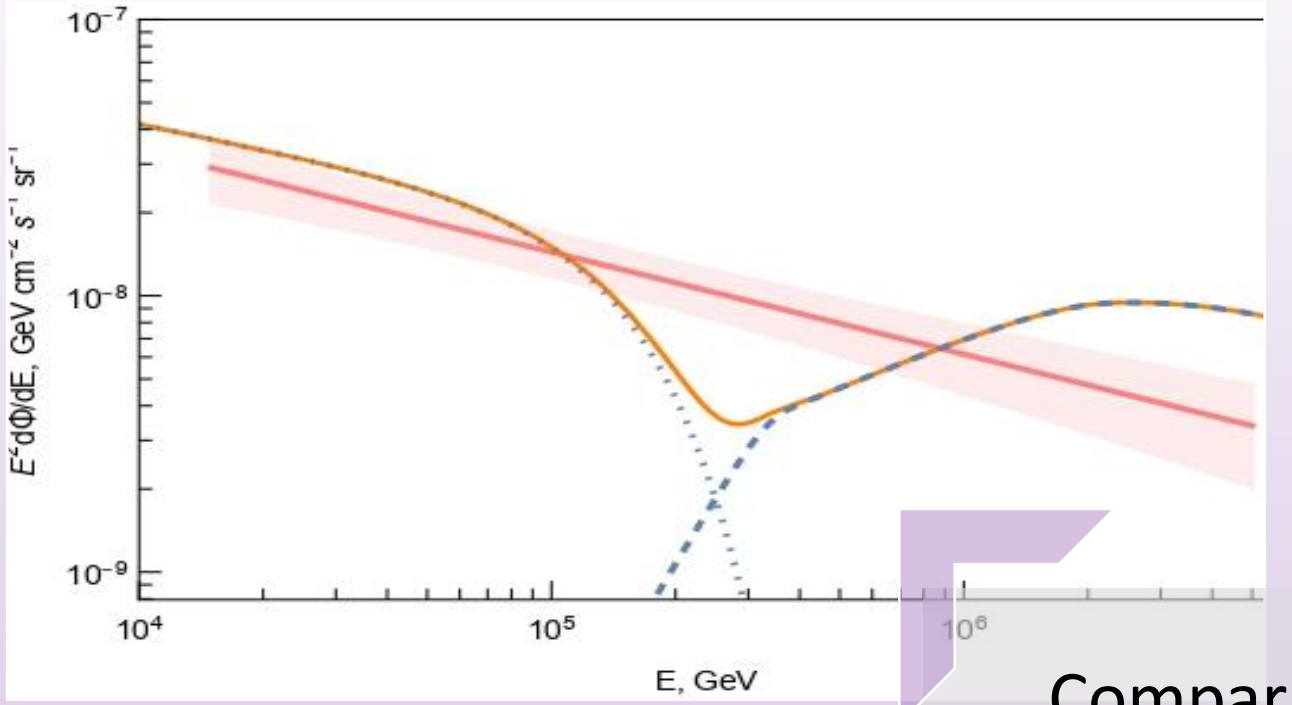


SMBH toy model



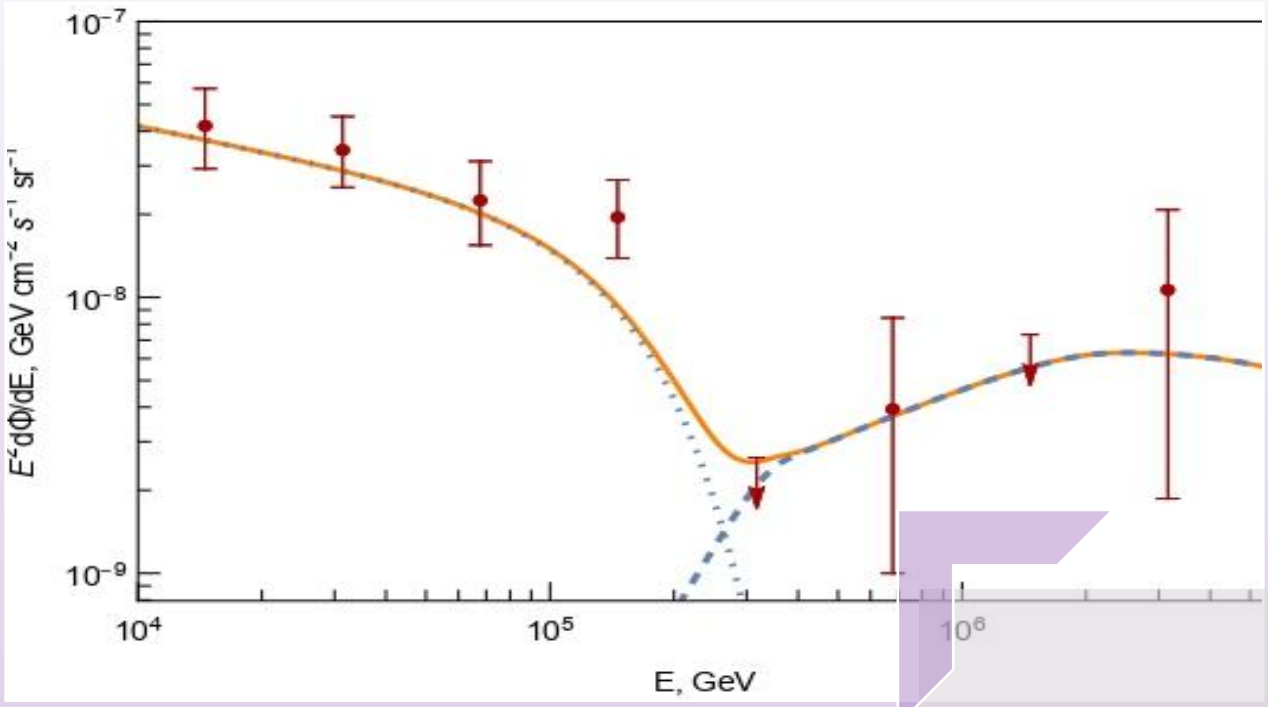
BH mass - Eddington ratio parameter space, calculated in accordance with BH magnetosphere toy model, which gets to estimate proton energies and finally provide a prediction of neutrino spectra

SMBH toy model



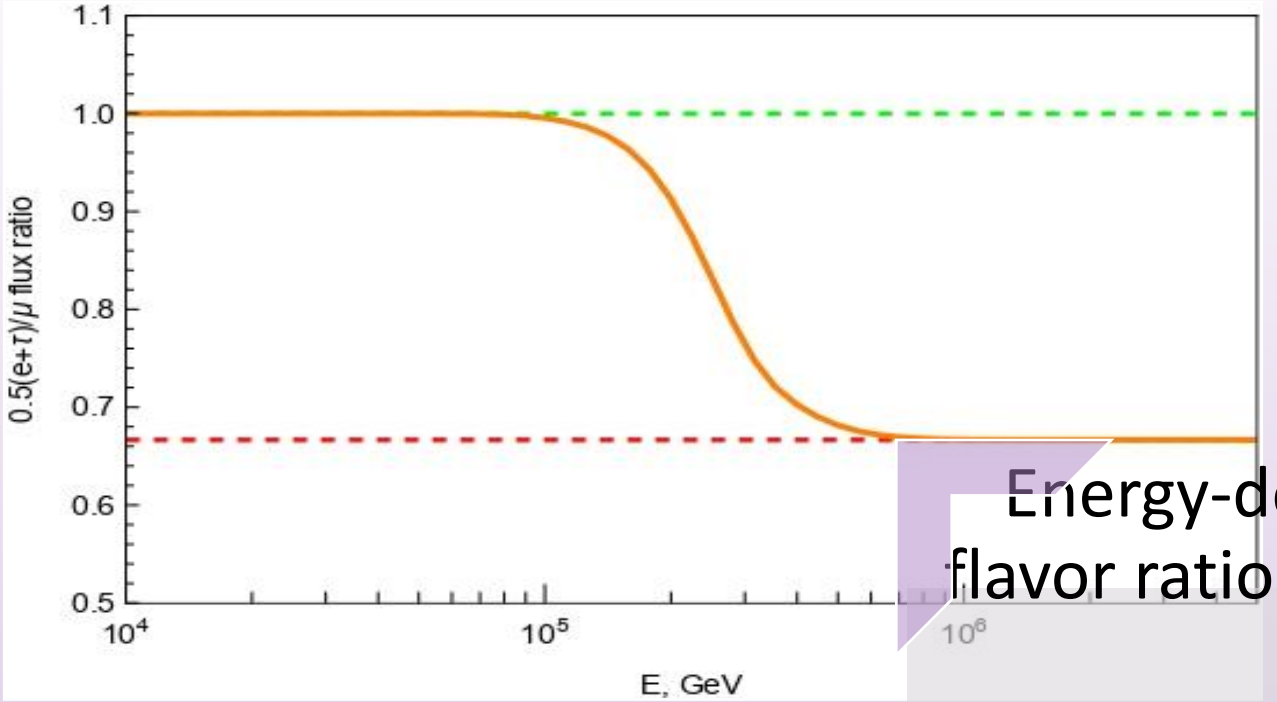
Comparison of the muon neutrino spectrum determined by IceCube and predictions of the toy model discussed in the text

SMBH toy model



Comparison of the e+tau neutrino spectrum determined by IceCube and predictions of the toy model discussed

SMBH toy model



Energy-dependent neutrino flavor ratio predicted by the toy model discussed in the text (solid curve). The dashed green line represents flavor equipartition, while the dashed red line corresponds to 2/3, predicted in the muon damping case

Conclusions

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It is presently unclear, whether the tension is caused by systematic uncertainties or by physical reasons.

1

We assumed that the reason for the discrepancy is related to the change of flavor composition

2

Then we estimated the magnetic field at
sources required for this switch

3

We constructed a quantitative toy model

4

We found that this model describes well the
spectra provided an additional component
with standard flavor content is added at low energies

5

Detailed studies of energy-dependent flavor ratios will become possible only with the next-generation neutrino telescopes

Thank you for your attention!

Questions?

Bibliography	https://arxiv.org/abs/2111.10299 (mu neutrinos data)
	https://arxiv.org/abs/2001.09520 (e+tau neutrinos data)
	https://arxiv.org/abs/1510.04023 (SMBH magnetospheres)