

Super-GZK Neutrinos

A. Ringwald

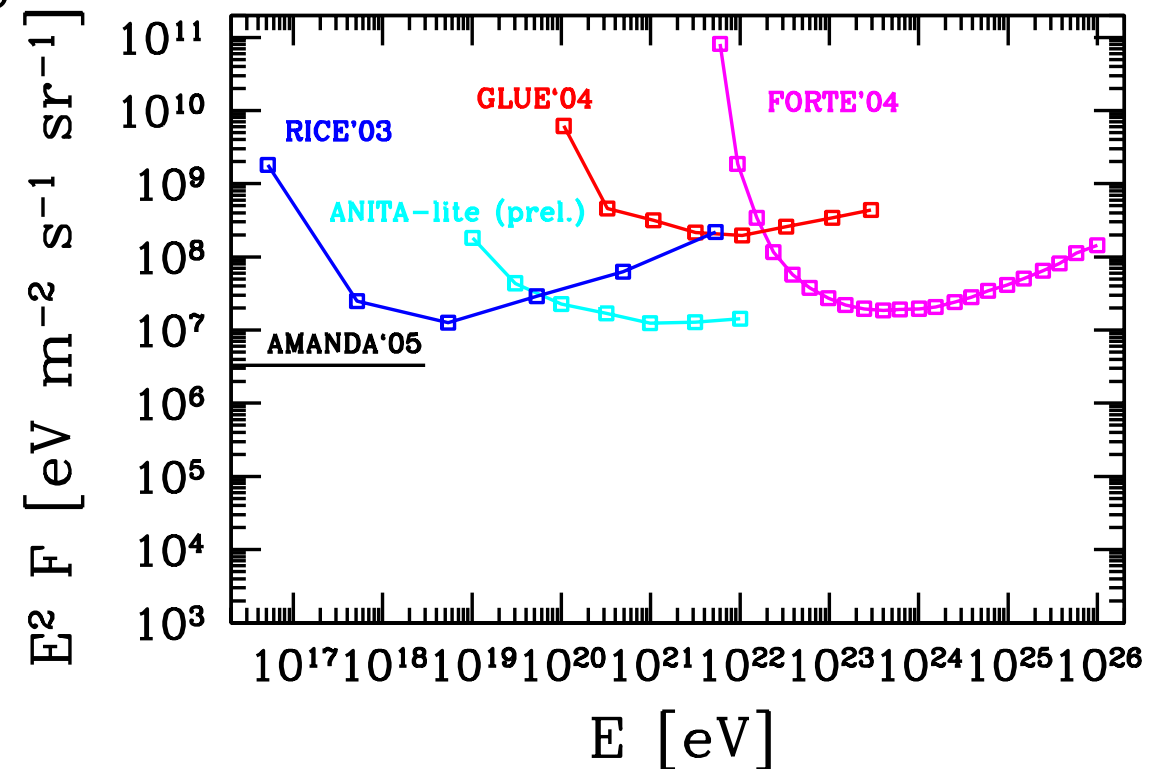
<http://www.desy.de/~ringwald>



**9th International Conference on
Topics in Astroparticle and Underground Physics (TAUP 2005)
September 10 - 14, 2005, University of Zaragoza, Zaragoza, Spain**

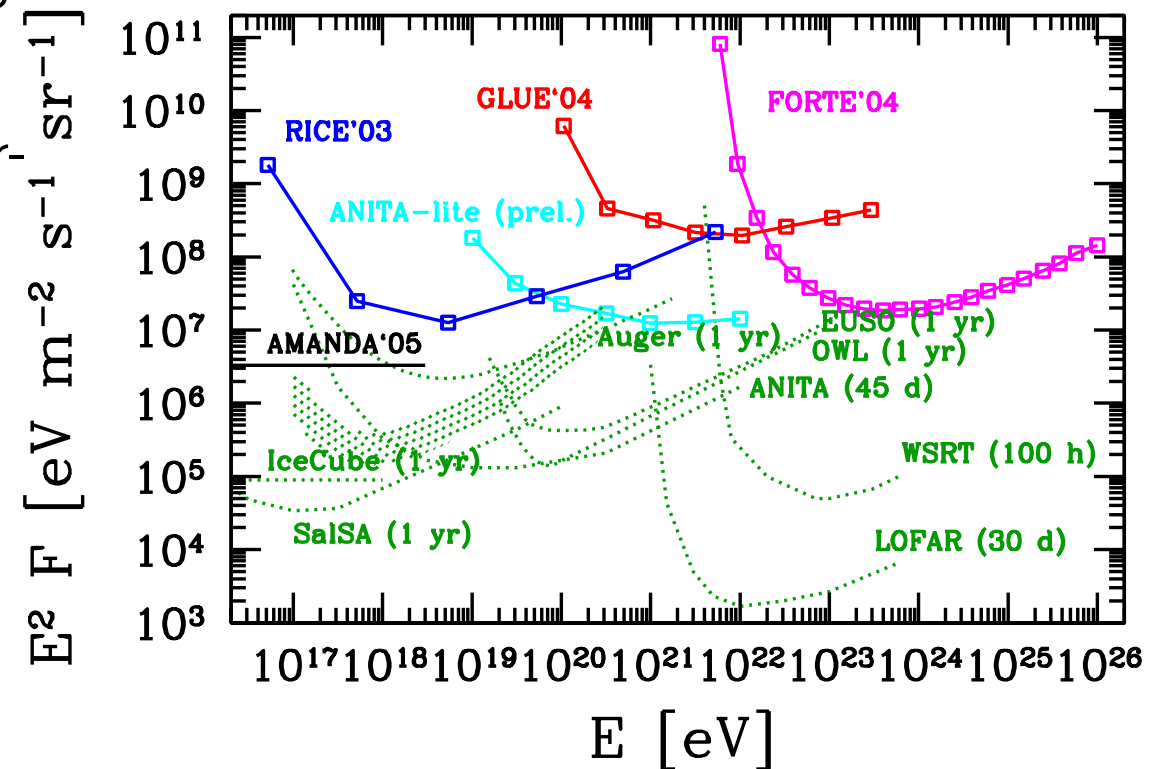
1. Introduction

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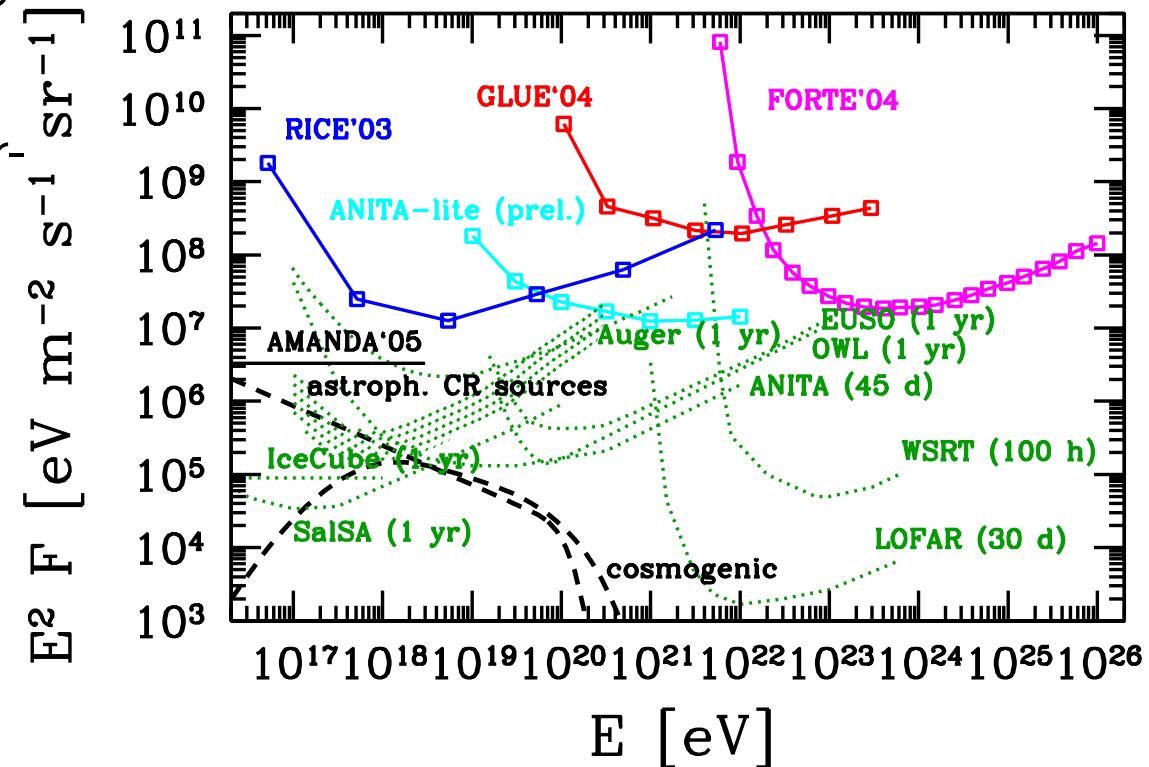
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$\Rightarrow E \geq 10^{16}$ eV:

\rightarrow **Astrophysics** of cosmic rays

$\Rightarrow E \geq 10^{17}$ eV:

\rightarrow **Particle physics** beyond **LHC**



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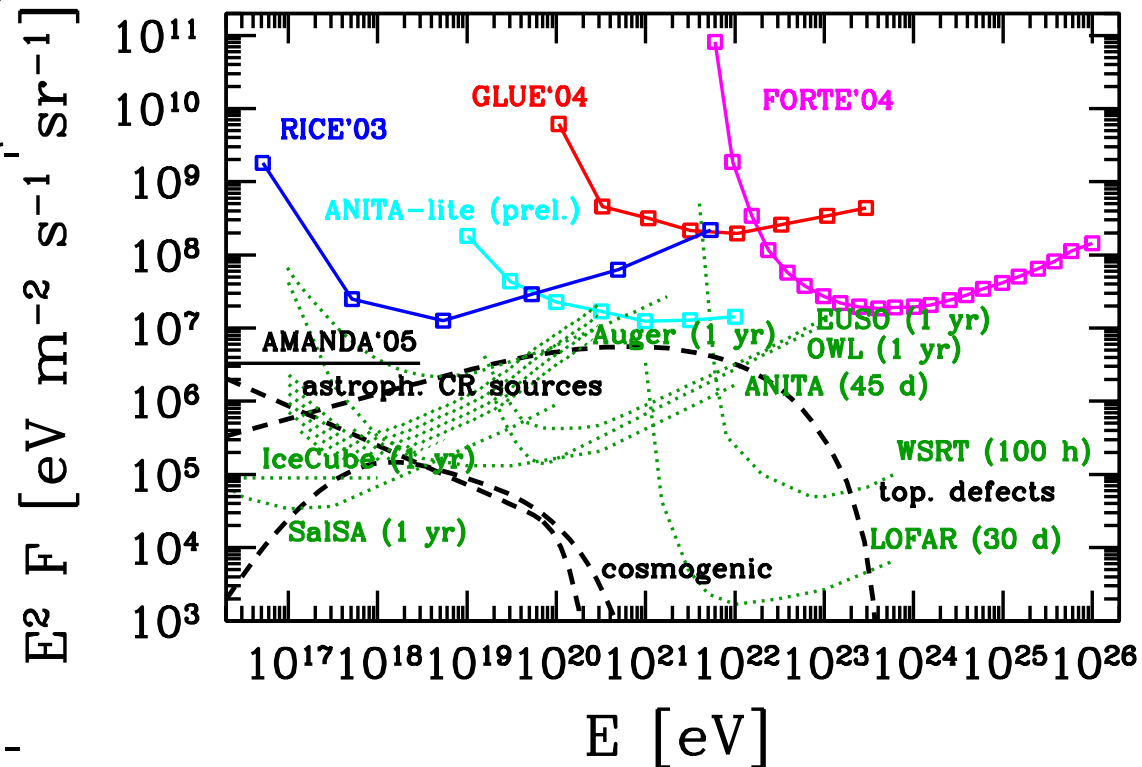
\rightarrow **Astrophysics** of cosmic rays

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\rightarrow **Particle physics** beyond **LHC**

$\Rightarrow E \geq 10^{21}$ eV:

\rightarrow **Cosmology**: relics of phase transitions; absorption on big bang relic neutrinos



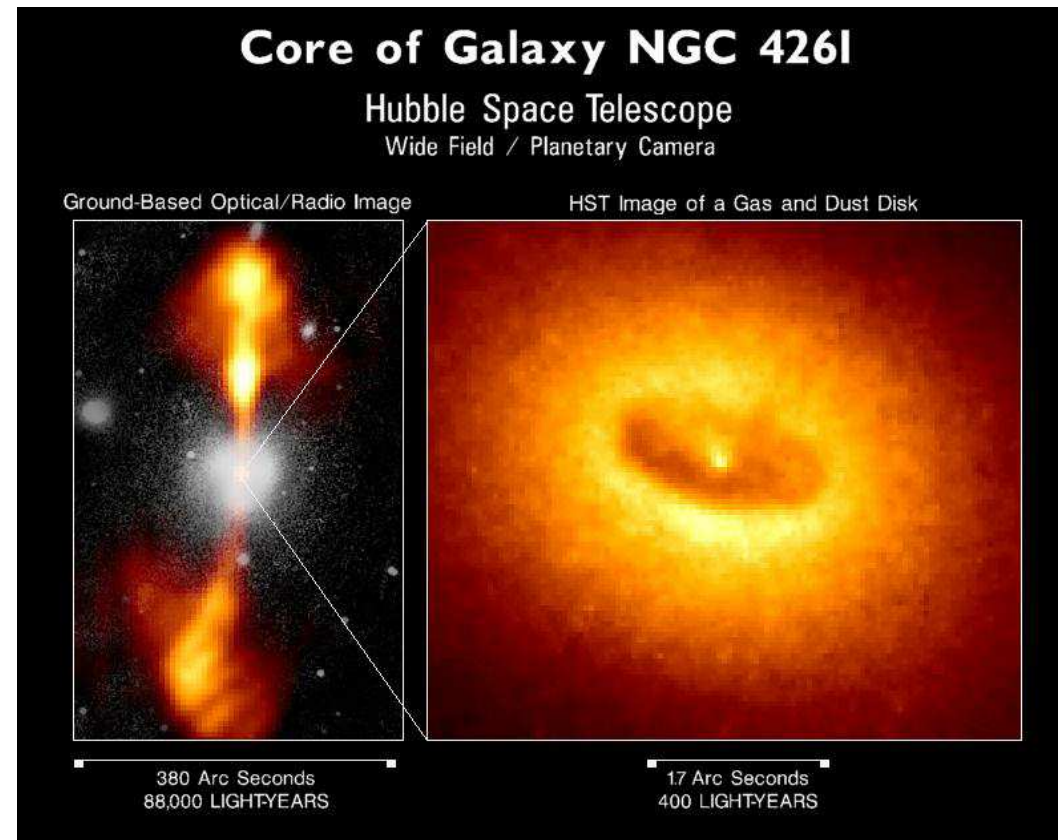
- **Further content:**

- 2. Sources and fluxes of super-GZK neutrinos**
- 3. Fun with super-GZK neutrinos**
- 4. Conclusions**

2. Sources and fluxes of super-GZK neutrinos

6

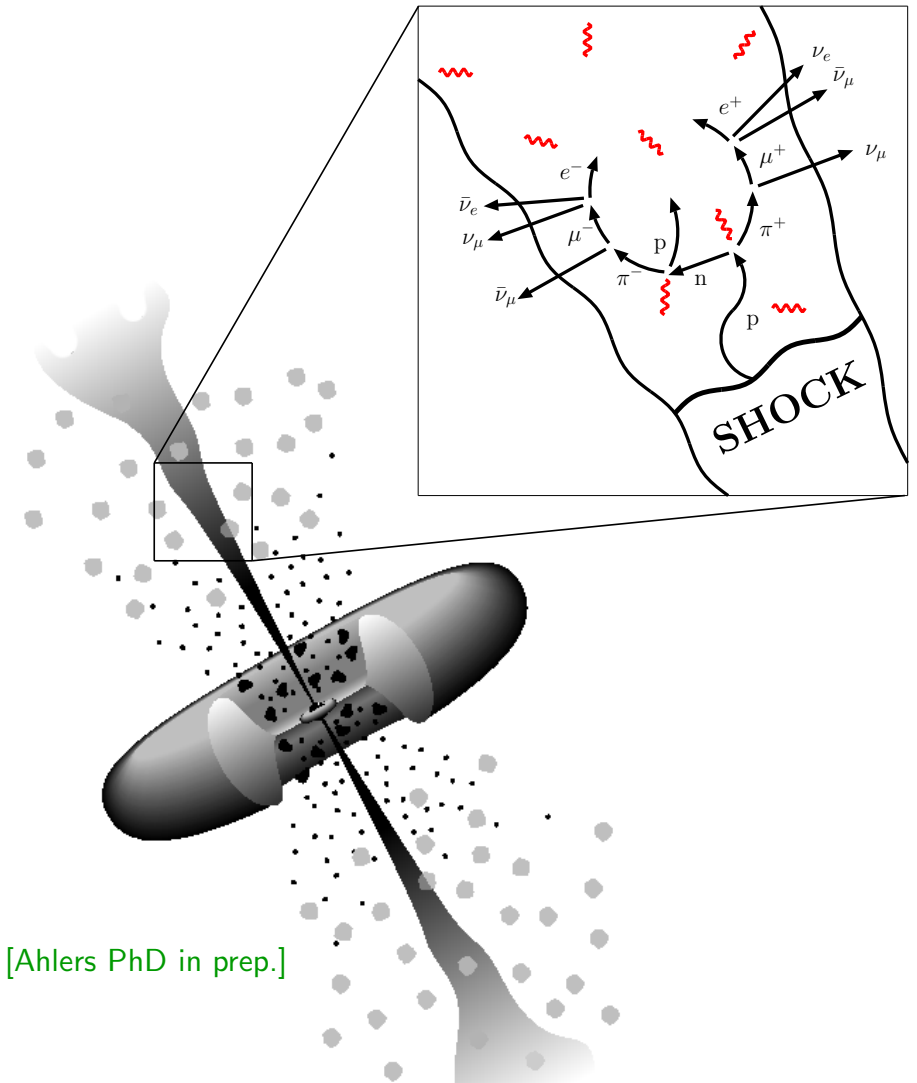
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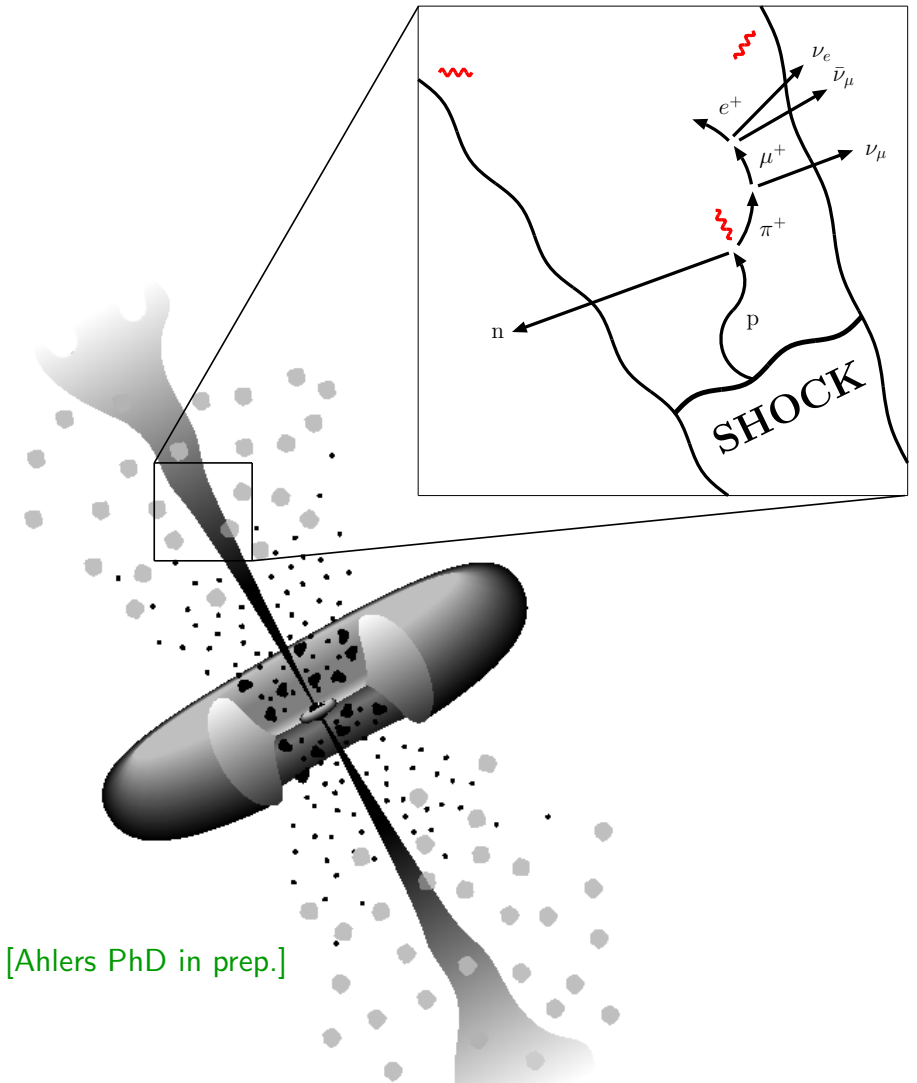


[Ahlers PhD in prep.]

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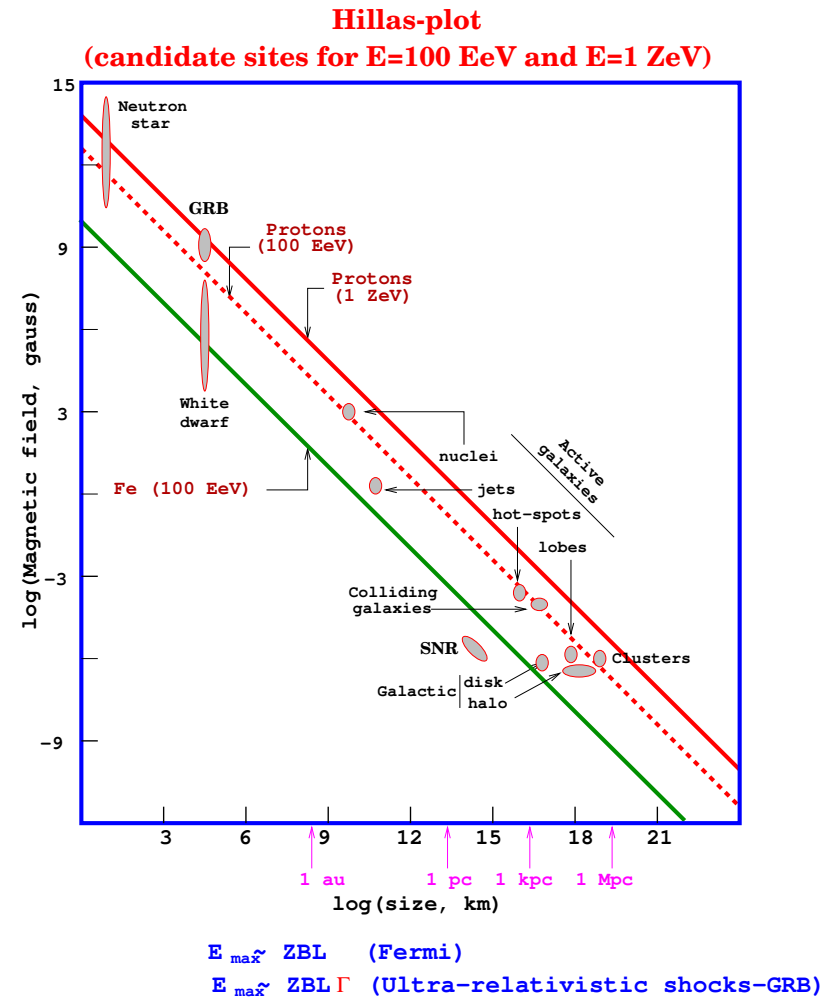
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[Pierre Auger Observatory]
TAUP 2005, Zaragoza, Spain

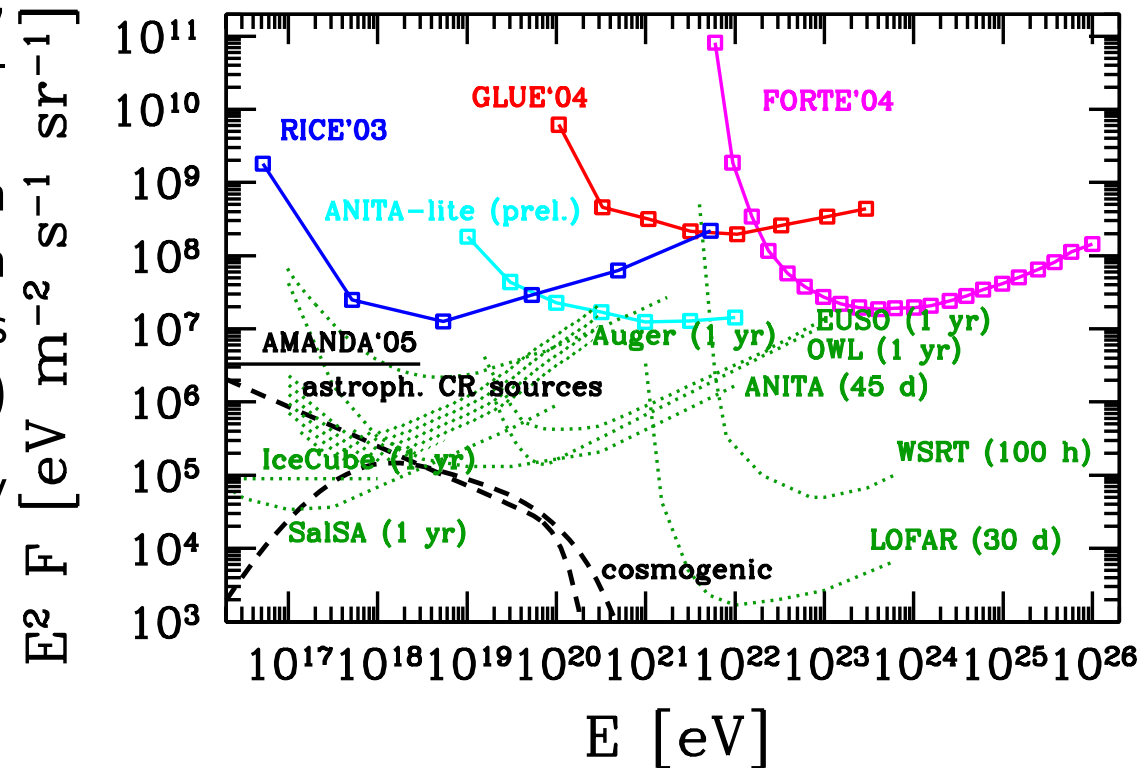
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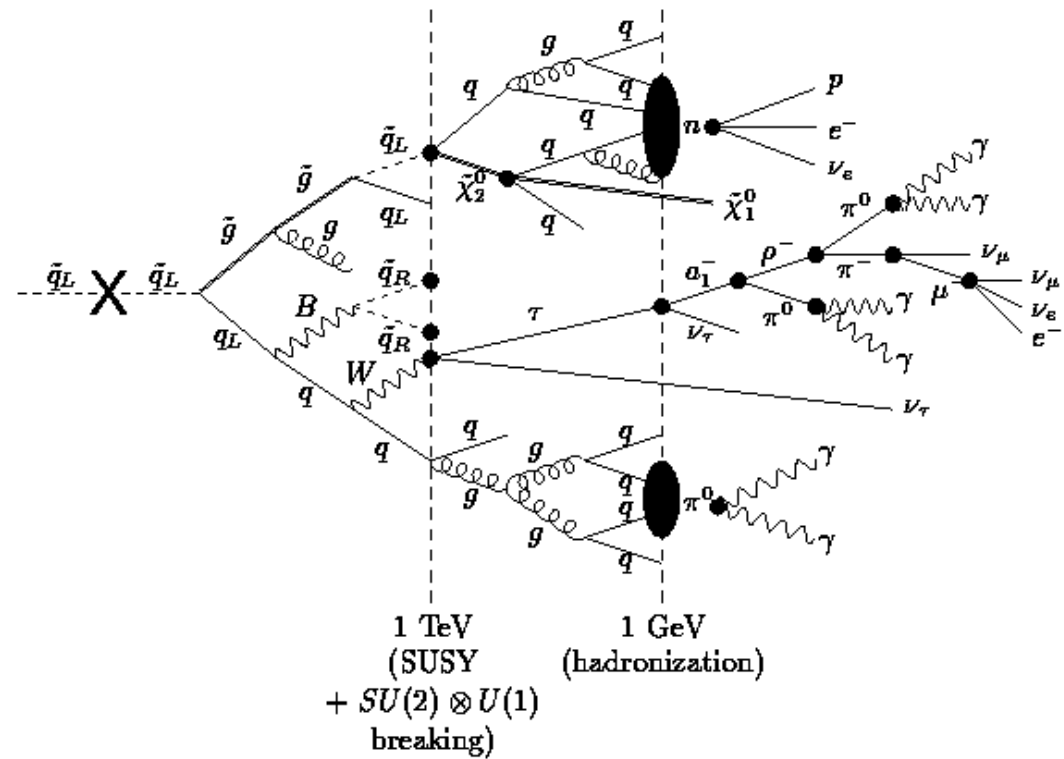
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Hillas: $E_p \lesssim 10^{21} \text{ eV} \Rightarrow E_\nu \lesssim 10^{20} \text{ eV}$

\Rightarrow Super-GZK ($E_\nu \gtrsim 10^{20} \text{ eV}$) neutrinos

- ← yet unknown acceleration sites
- ← other acceleration mechanism
- ← **decay of superheavy particles**

A. Ringwald (DESY)



[Barbot, Drees '02]

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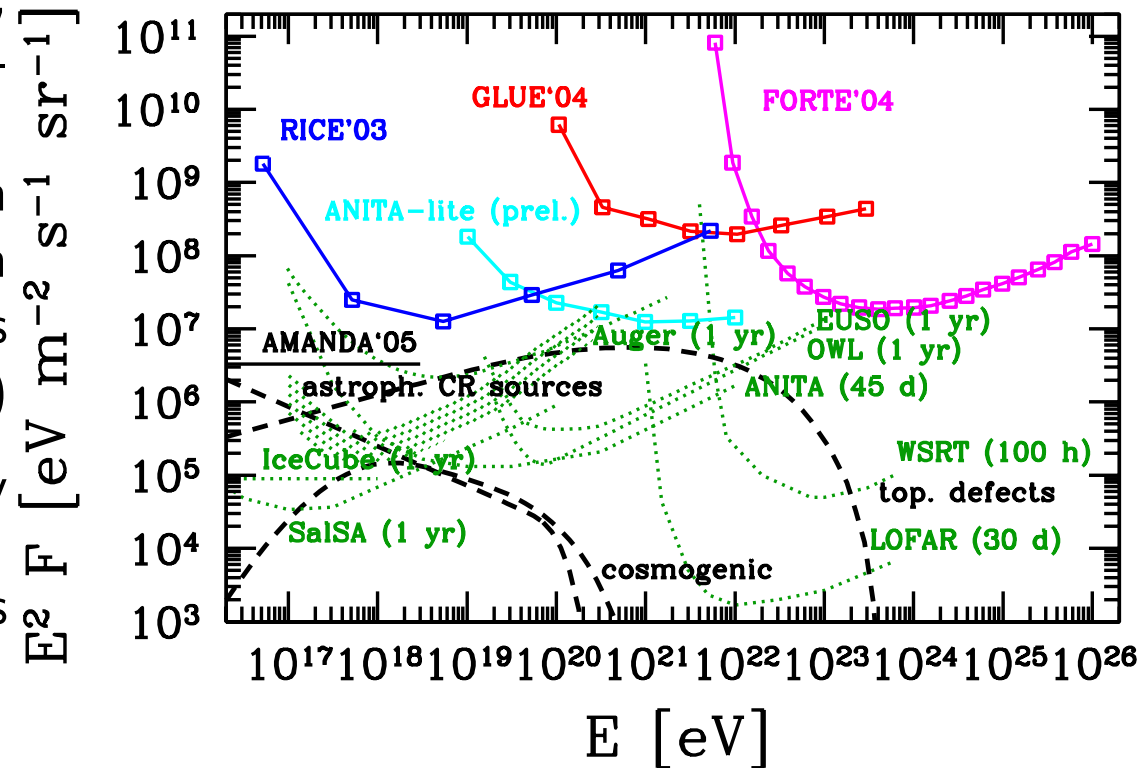
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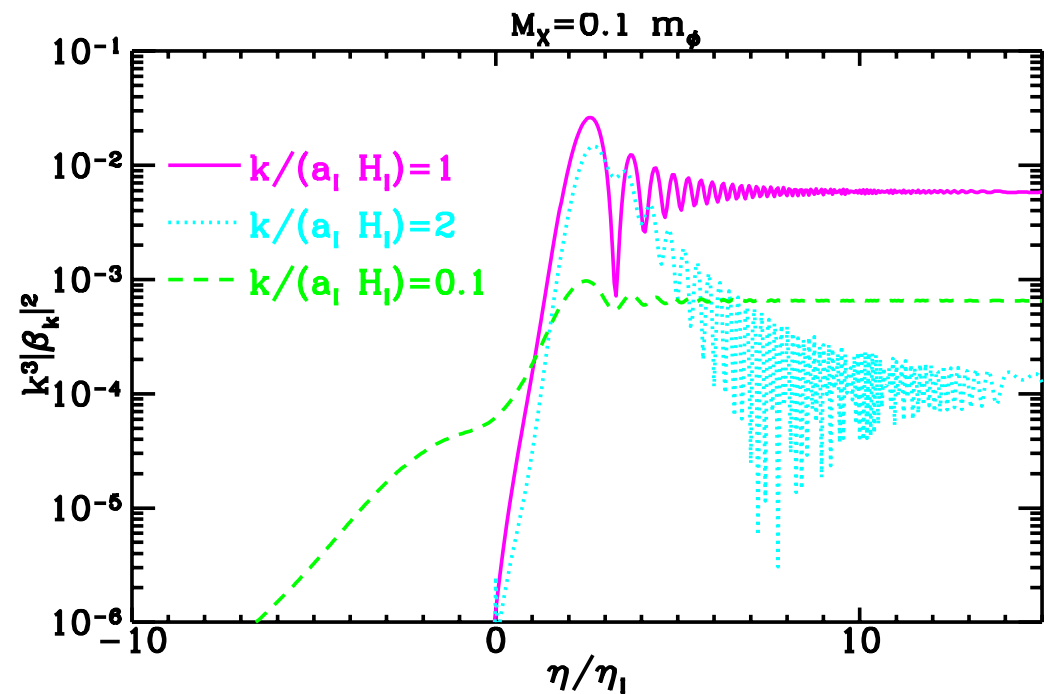
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Top-down scenarios for super-GZK neutrinos

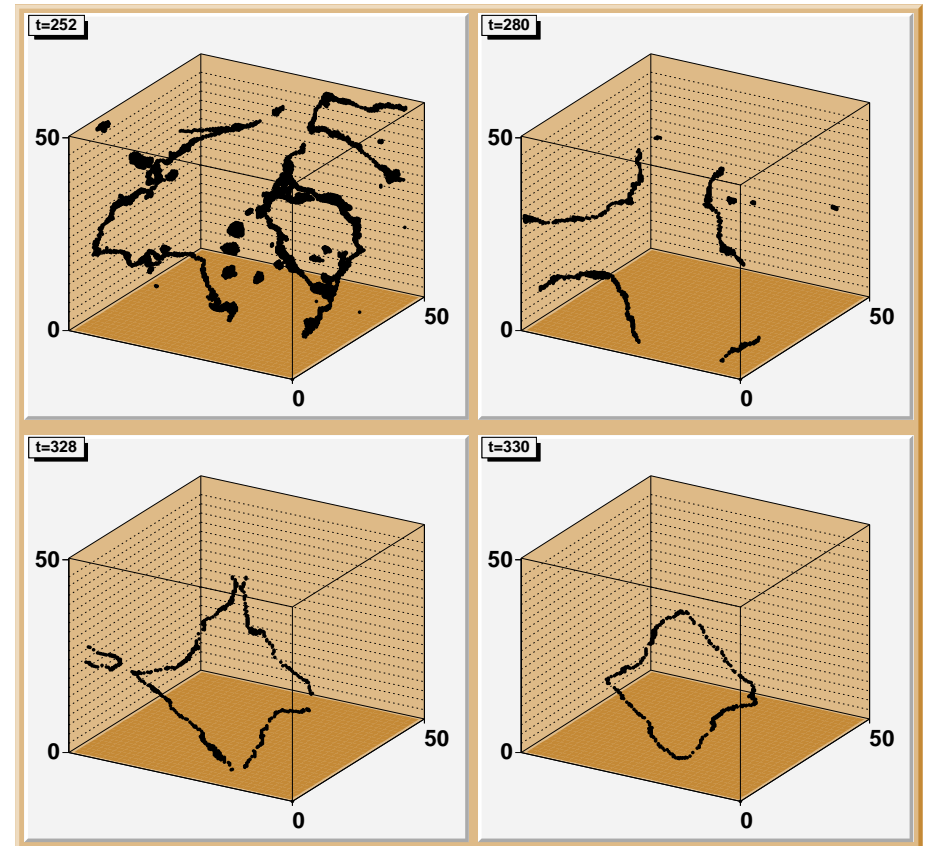
- Existence of superheavy particles with $10^{12} \text{ GeV} \lesssim m_X \lesssim 10^{16} \text{ GeV}$, produced during and after inflation through e.g.
 - particle creation in time-varying gravitational field



[Kolb, Chung, Riotto '98]

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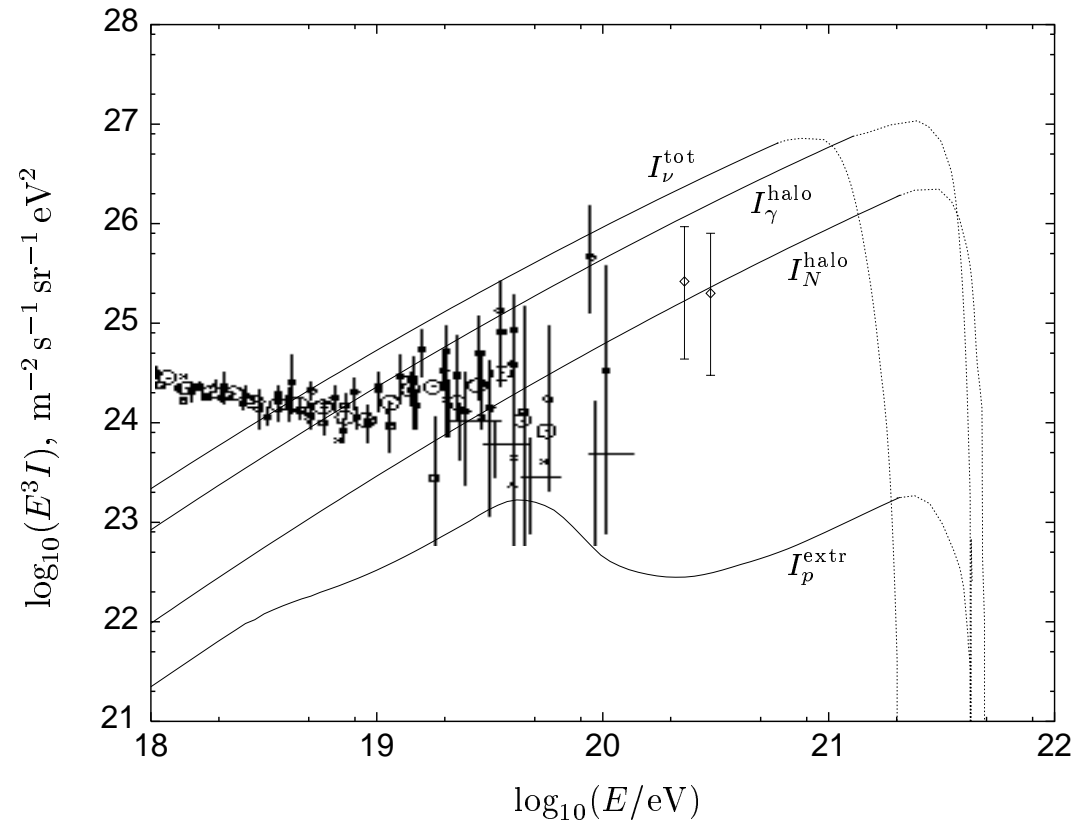
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 - decomposition of topological defects, formed during preheating, into their constituents



[Tkachev, Khlebnikov, Kofman, Linde '98]

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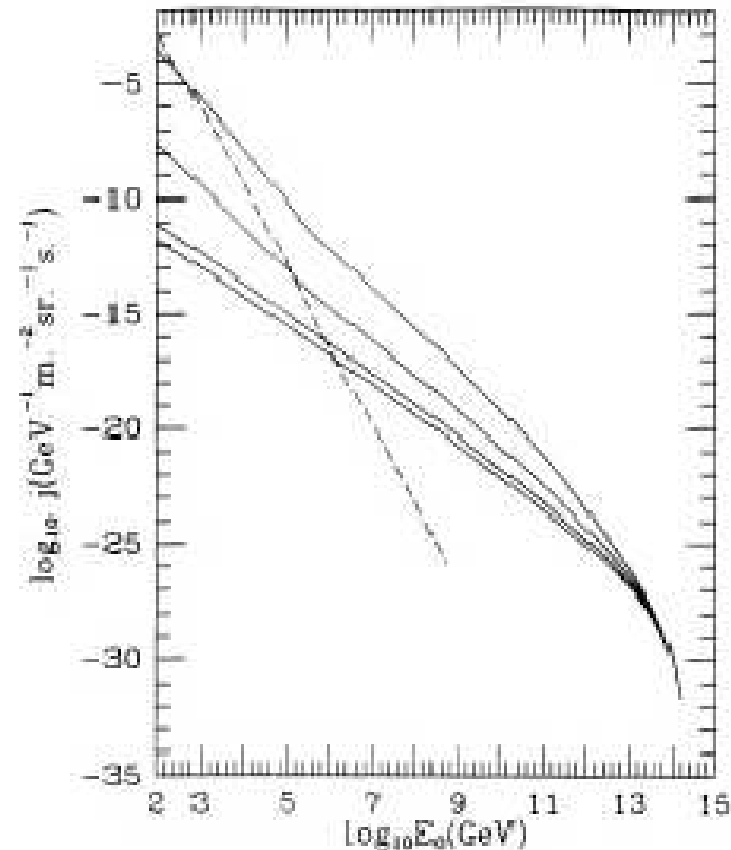
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- ⇒ super-GZK ν 's from decay or annihilation of superheavy dark matter (for $\tau_X \gtrsim \tau_U$)
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[Berezinsky, Kachelriess, Vilenkin '97]

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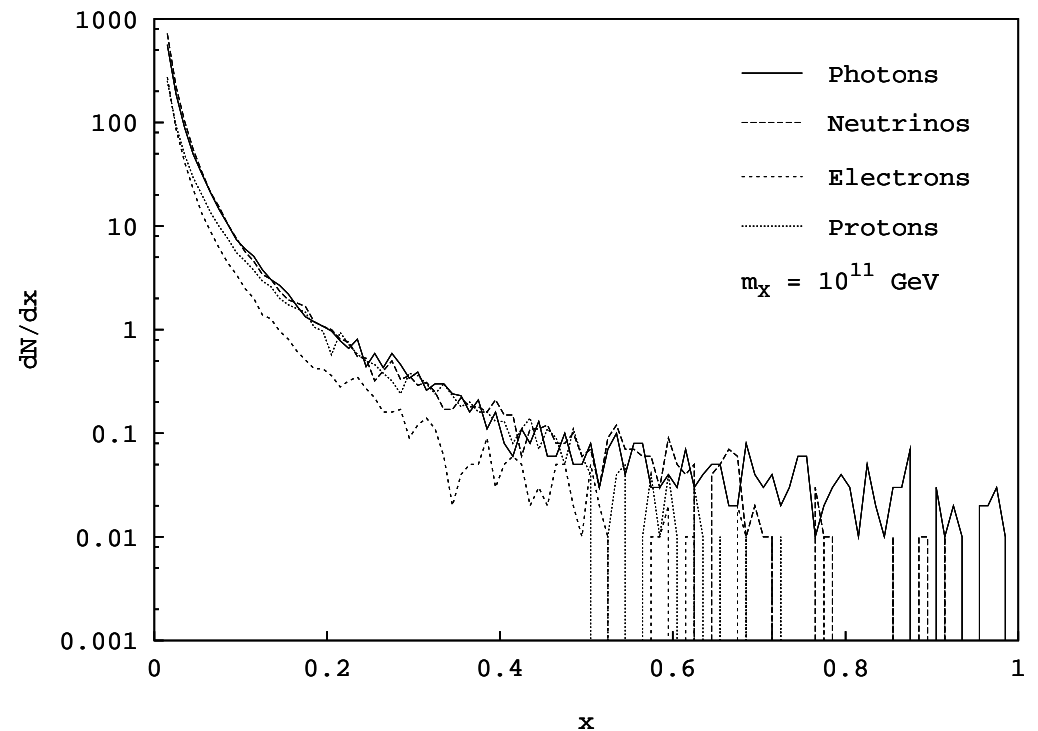
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 - ⇒ super-GZK ν 's from topological defects



[Bhattacharjee, Hill, Schramm '92]

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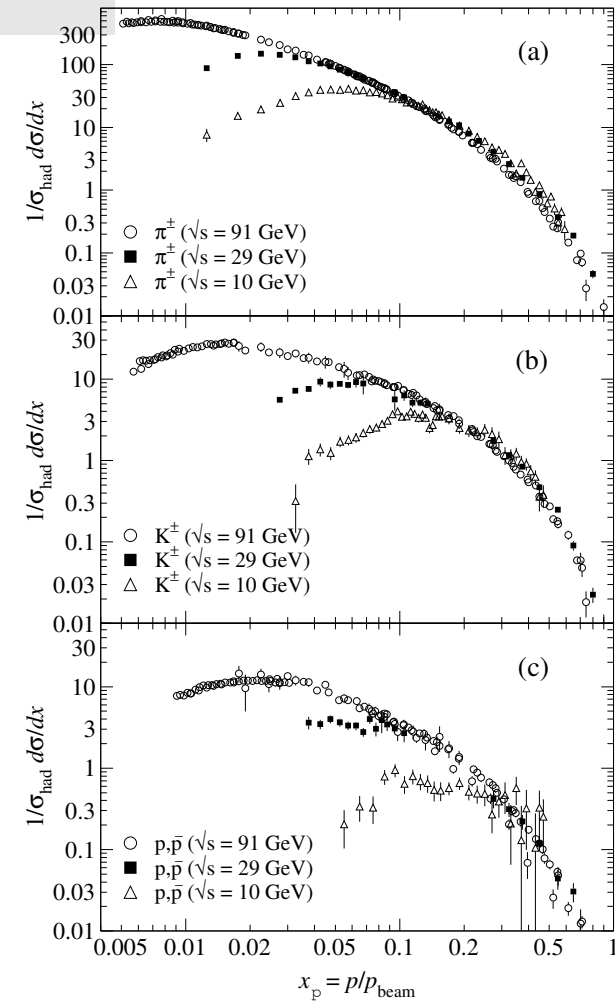
- **Injection spectra:** fragmentation functions $D_i(x, \mu)$, $i = p, e, \gamma, \nu$, determined via
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[Birkel, Sarkar '98]

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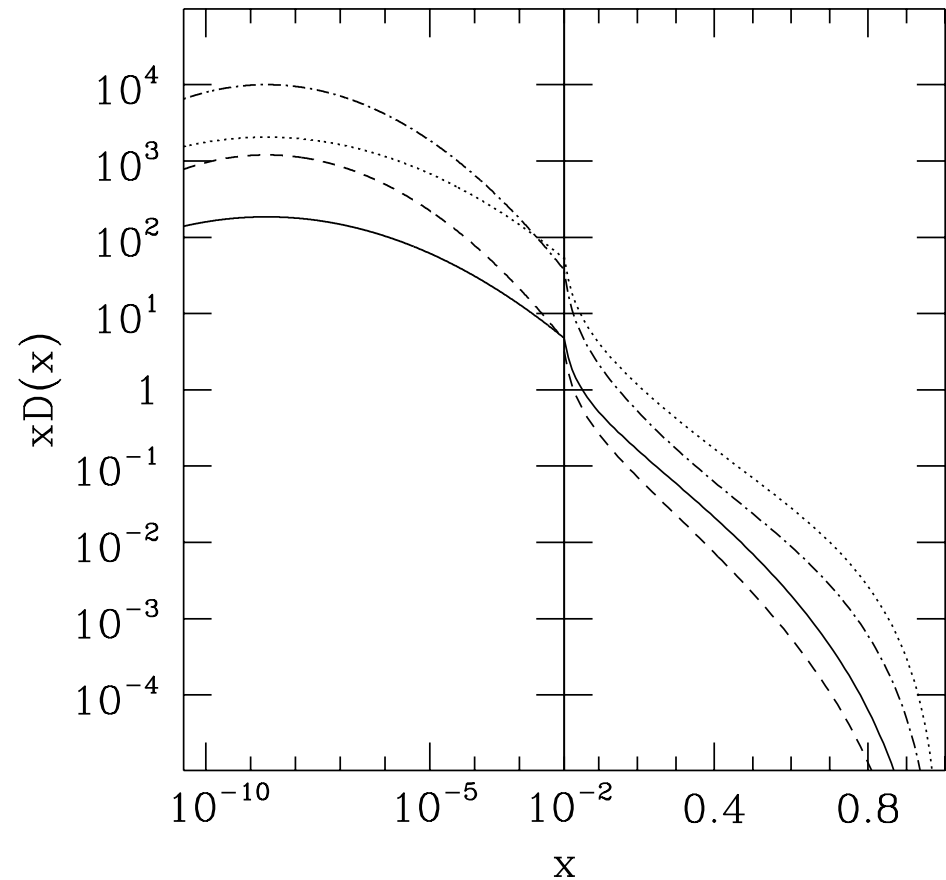


[Particle Data Group '04]

TAUP 2005, Zaragoza, Spain

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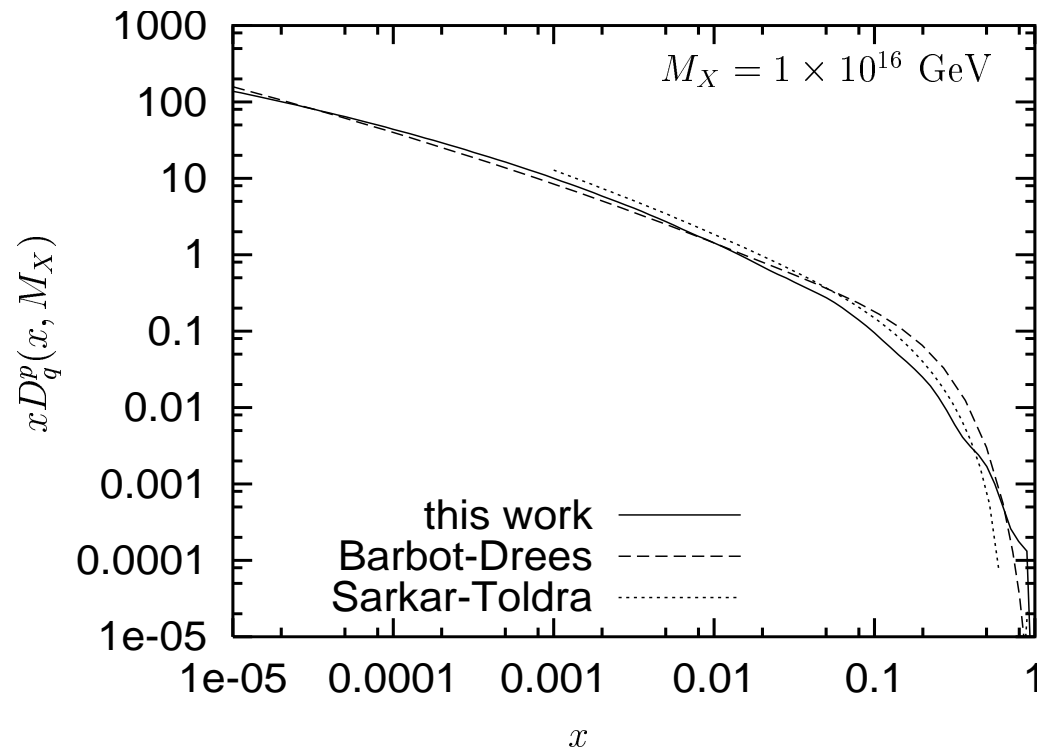


[Fodor, Katz '01]

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⇒ Reliably predicted!



[Aloisio, Berezinsky, Kachelriess '04]

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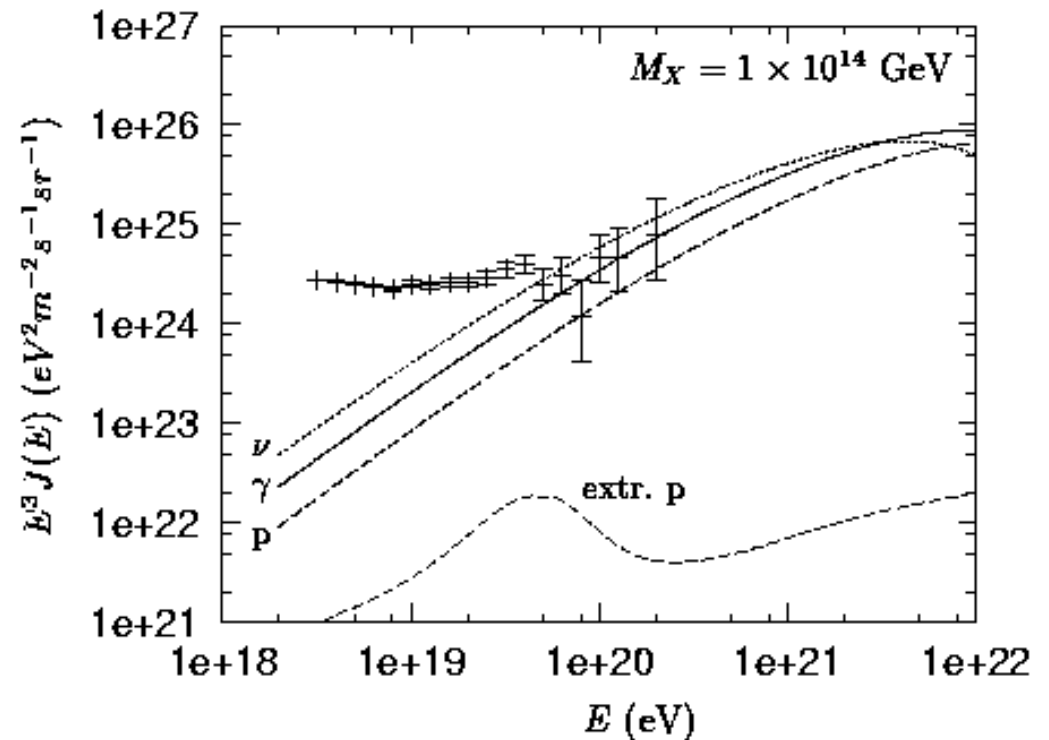
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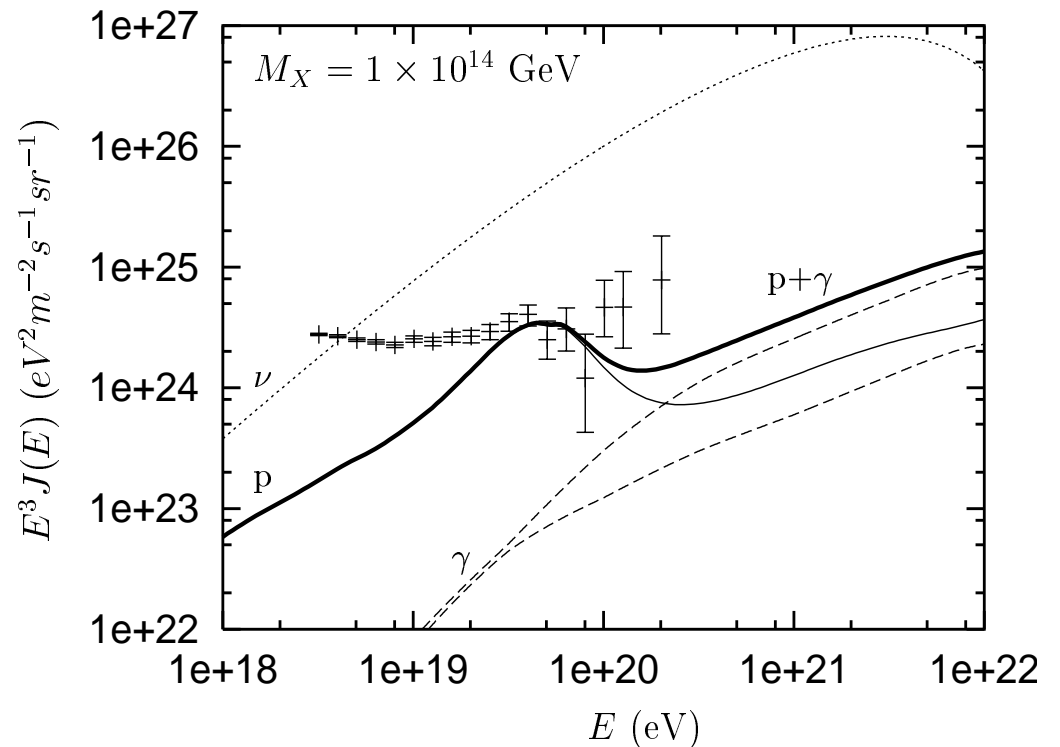
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- **Spectra at Earth:**

- for superheavy dark matter, injection nearby: $j_\nu \sim j_\gamma \sim j_p$
- for topological defects, injection far away: $j_\nu \gg j_\gamma \sim j_p$



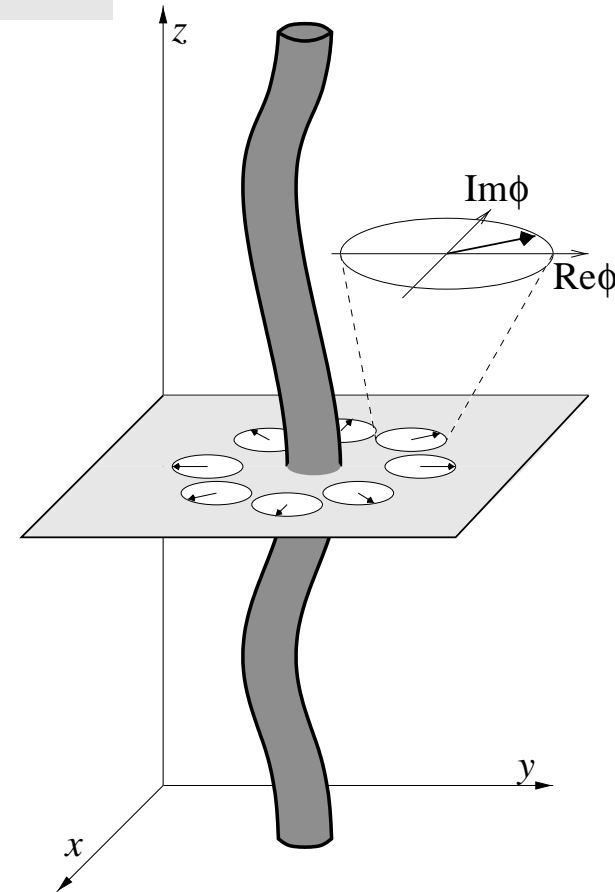
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Top-down scenarios for super-GZK neutrinos

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 - **Superheavy dark matter:** need symmetry to prevent fast X decay
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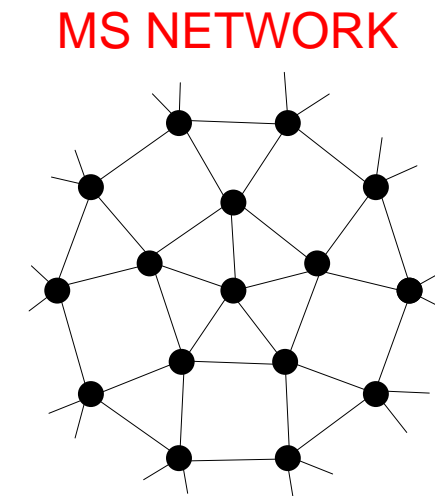
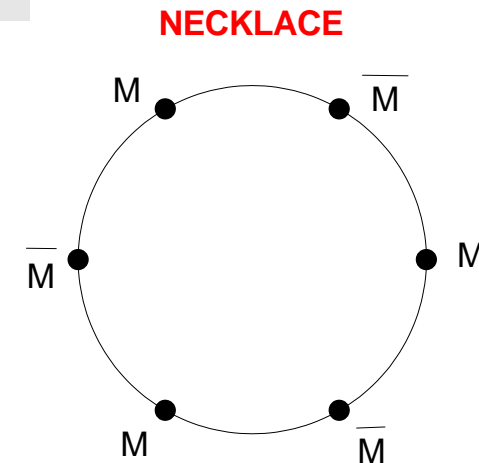
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 - * $G \rightarrow H \times U(1)$ SB: monopoles
 - * $U(1)$ SB: ordinary or superconducting strings



[Rajantie '03]

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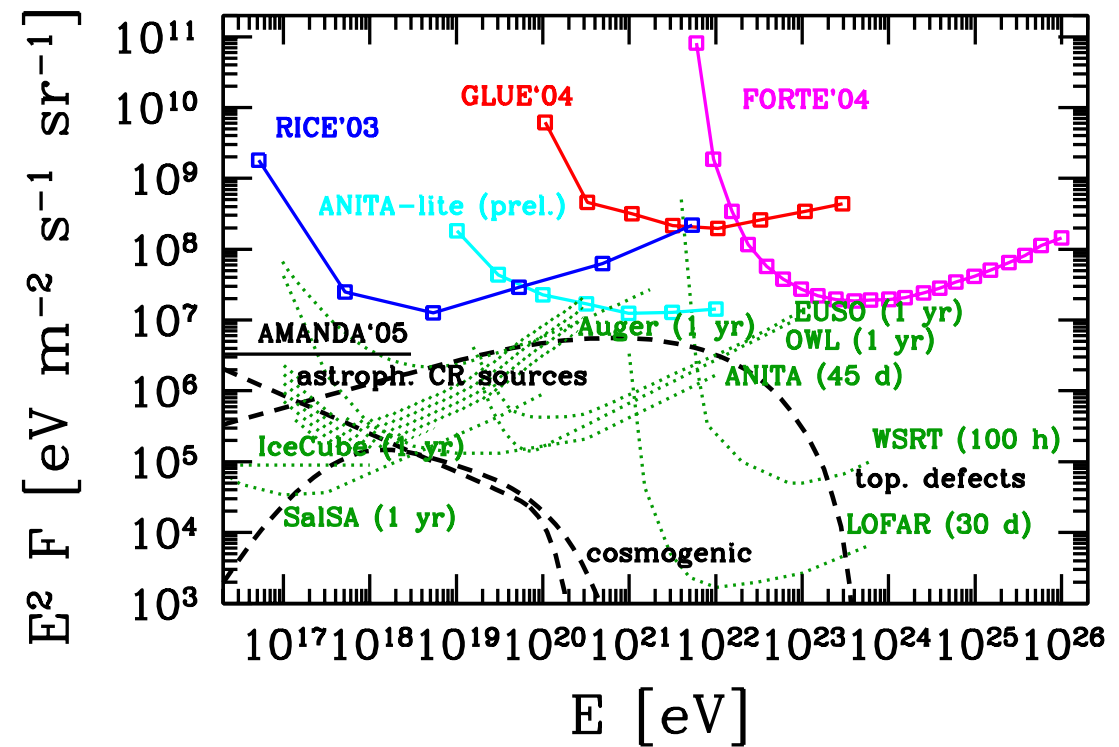


[Berezinsky '05]

TAUP 2005, Zaragoza, Spain

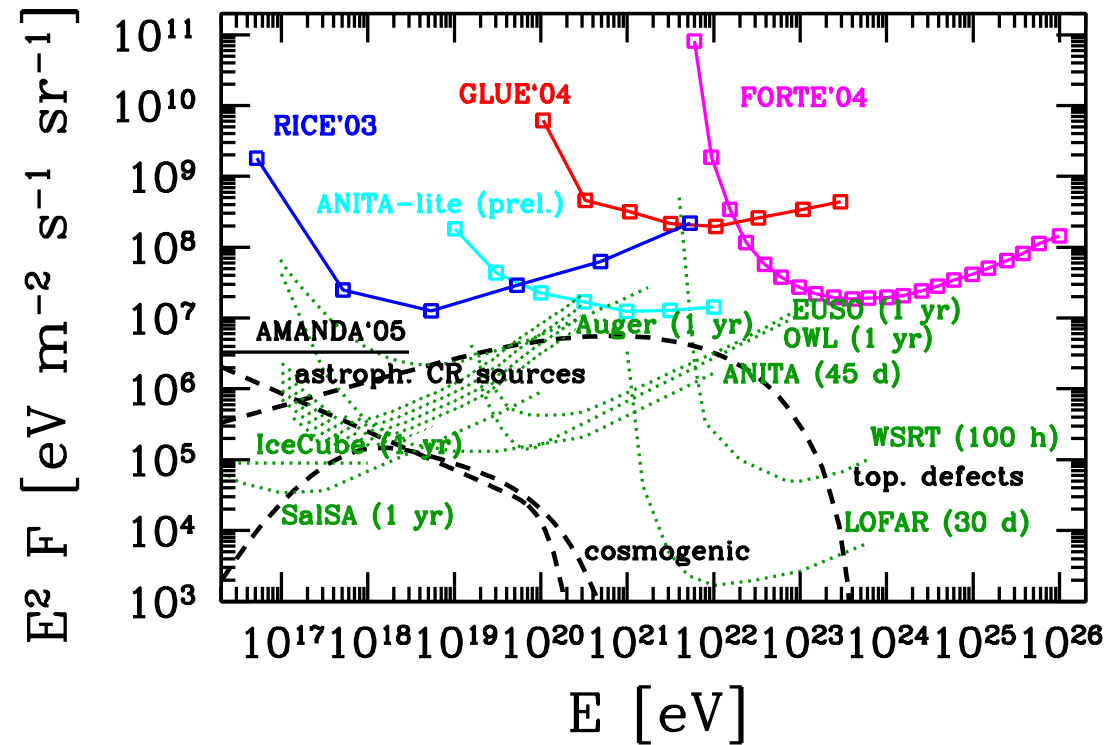
3. Fun with super-GZK neutrinos

- Super-GZK ν 's in reach!
- Strong impact of measurement for
 - particle physics
 - cosmology



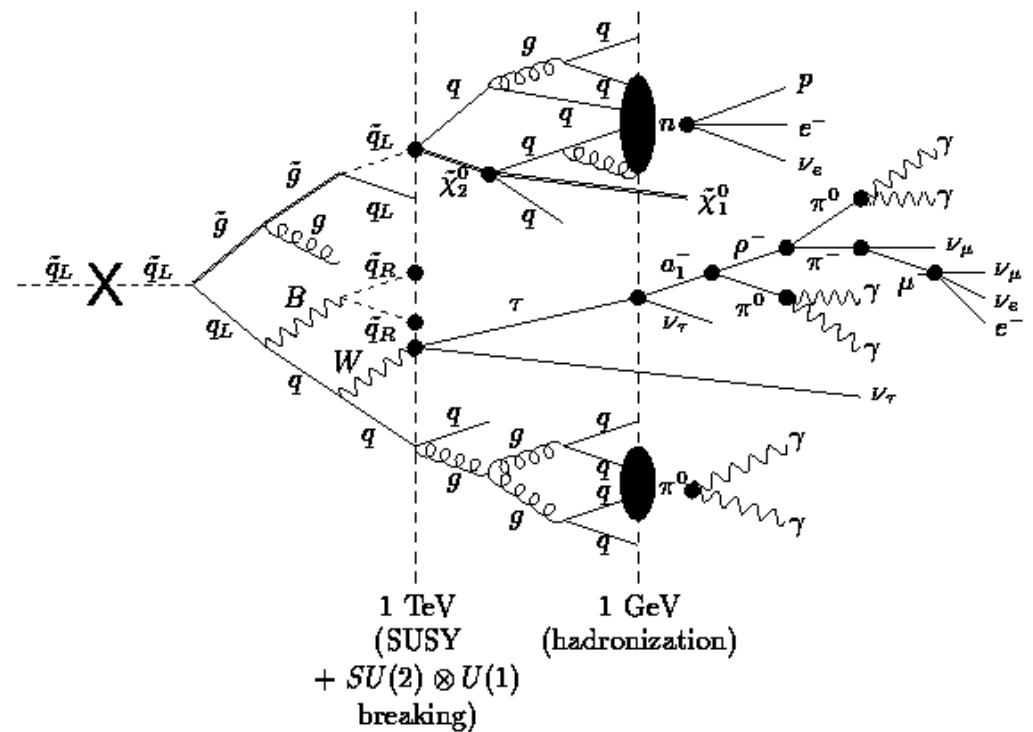
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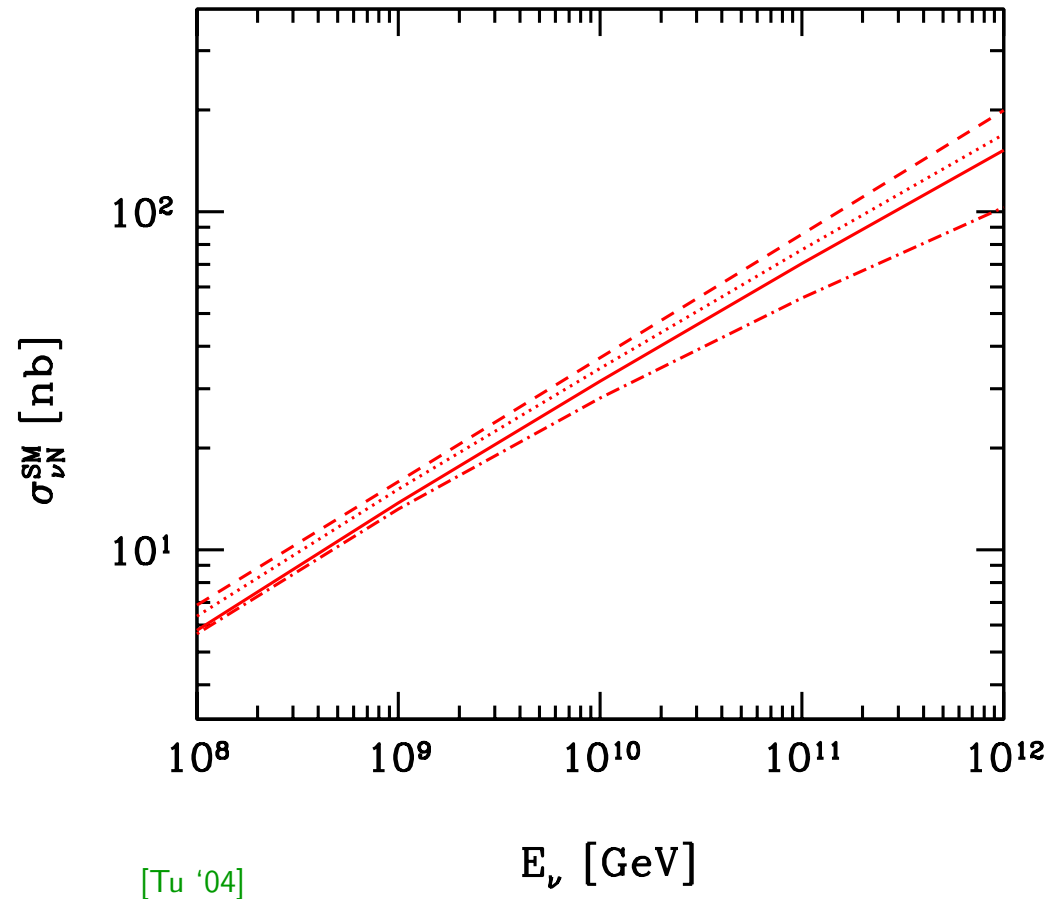
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[Barbot, Drees '02]

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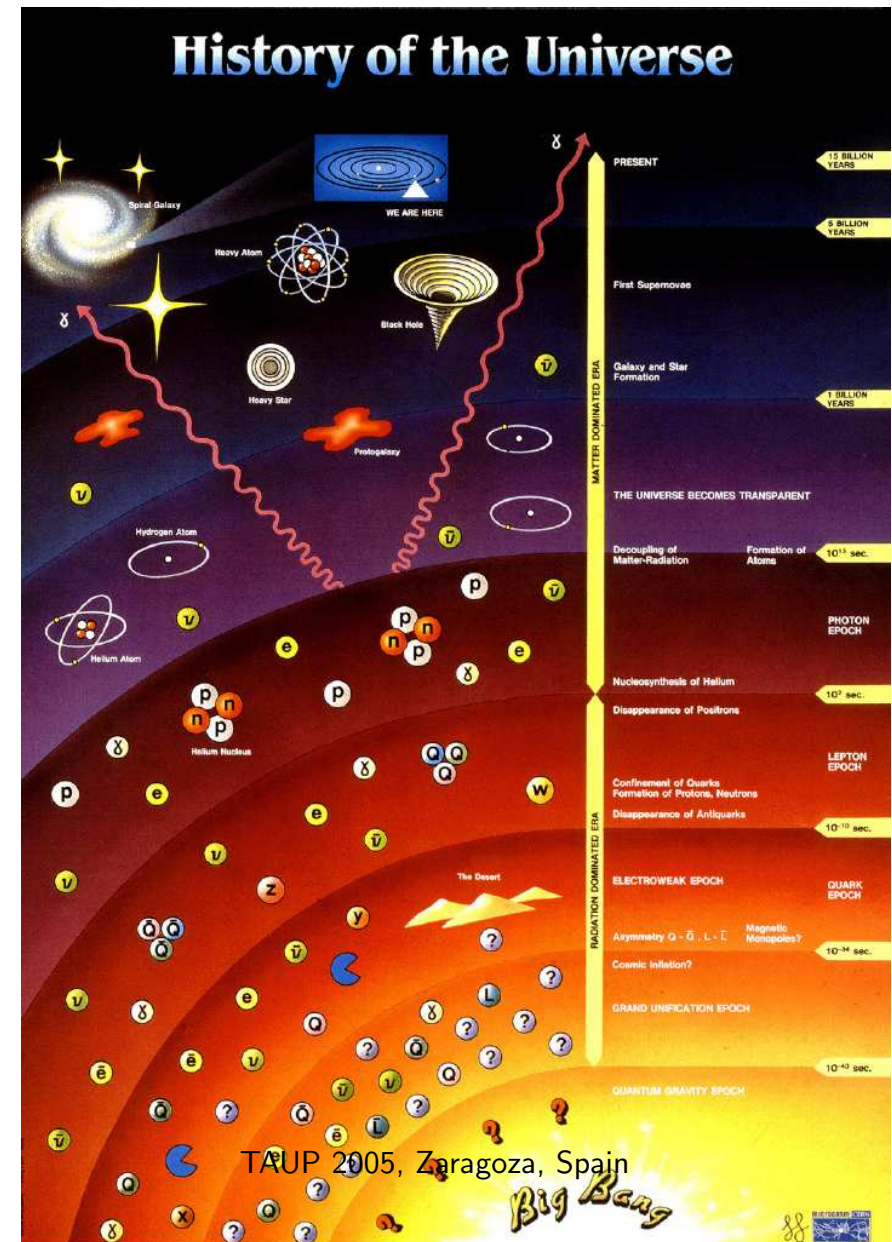
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 - **cosmology**
 - * window on early phase transition
 - * Hubble expansion rate $H(z)$
 - * existence of the big bang relic neutrino background ($C\nu B$)

A. Ringwald (DESY)



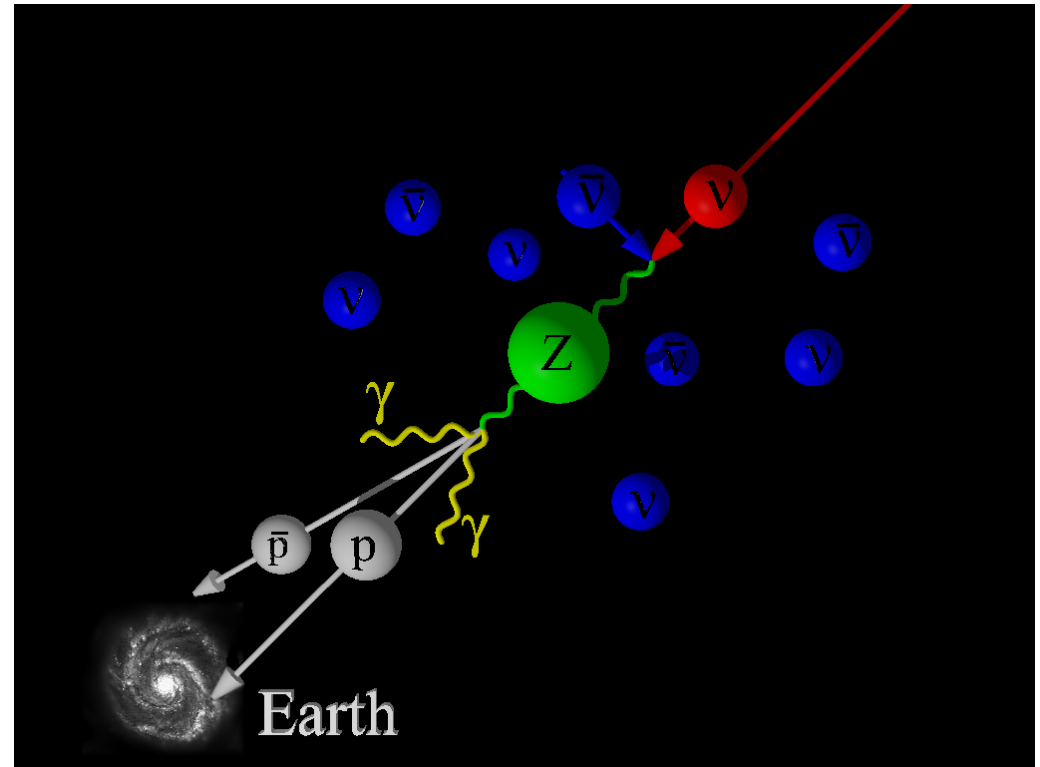
Absorption of super-GZK neutrinos by the $C\nu B$

31

- At the resonance energies

$$E_\nu^{\text{res}} = \frac{m_Z^2}{2m_\nu} \simeq 4 \times 10^{21} \text{ eV} \left(\frac{\text{eV}}{m_\nu} \right)$$

super-GZK neutrinos annihilate with relic neutrinos into Z bosons



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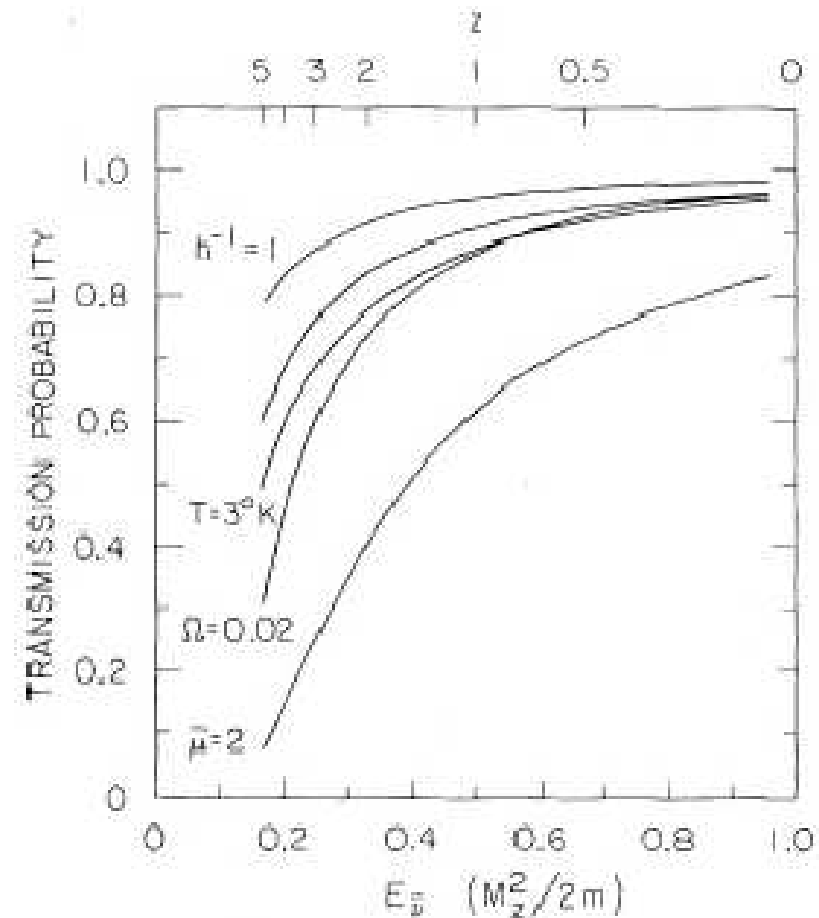
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⇒ Absorption dips in super-GZK neutrino spectra



[Weiler '82]

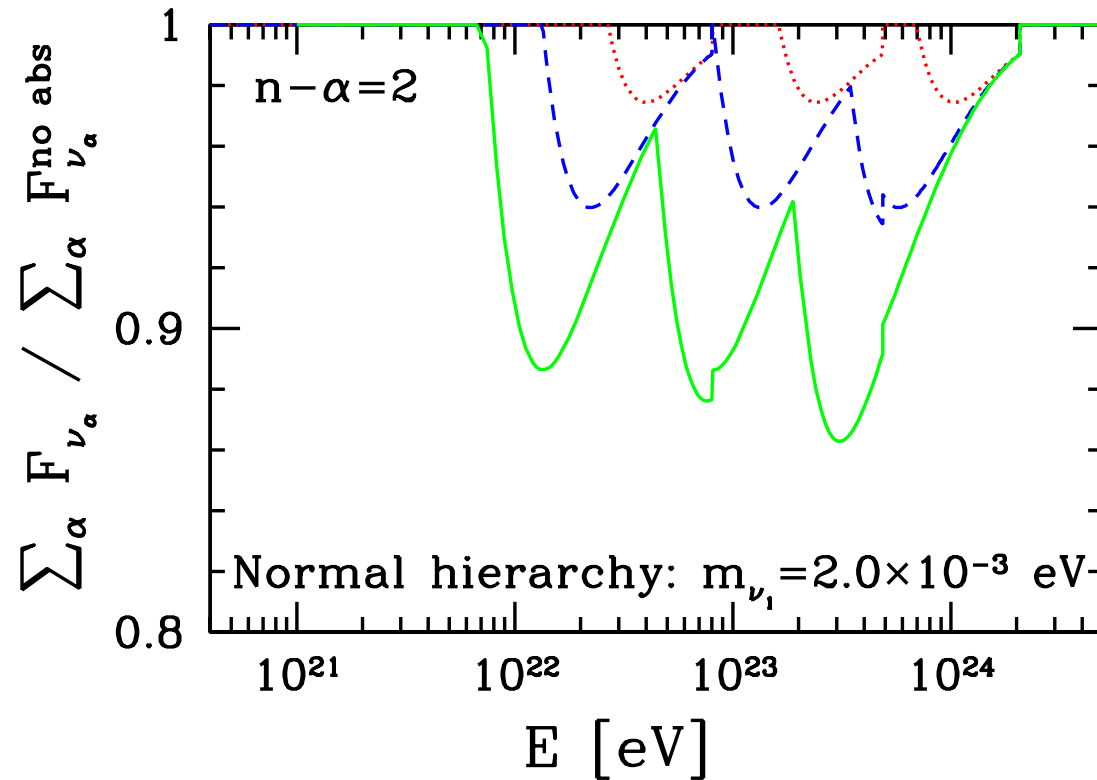
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[Eberle,AR,Song,Weiler '04]

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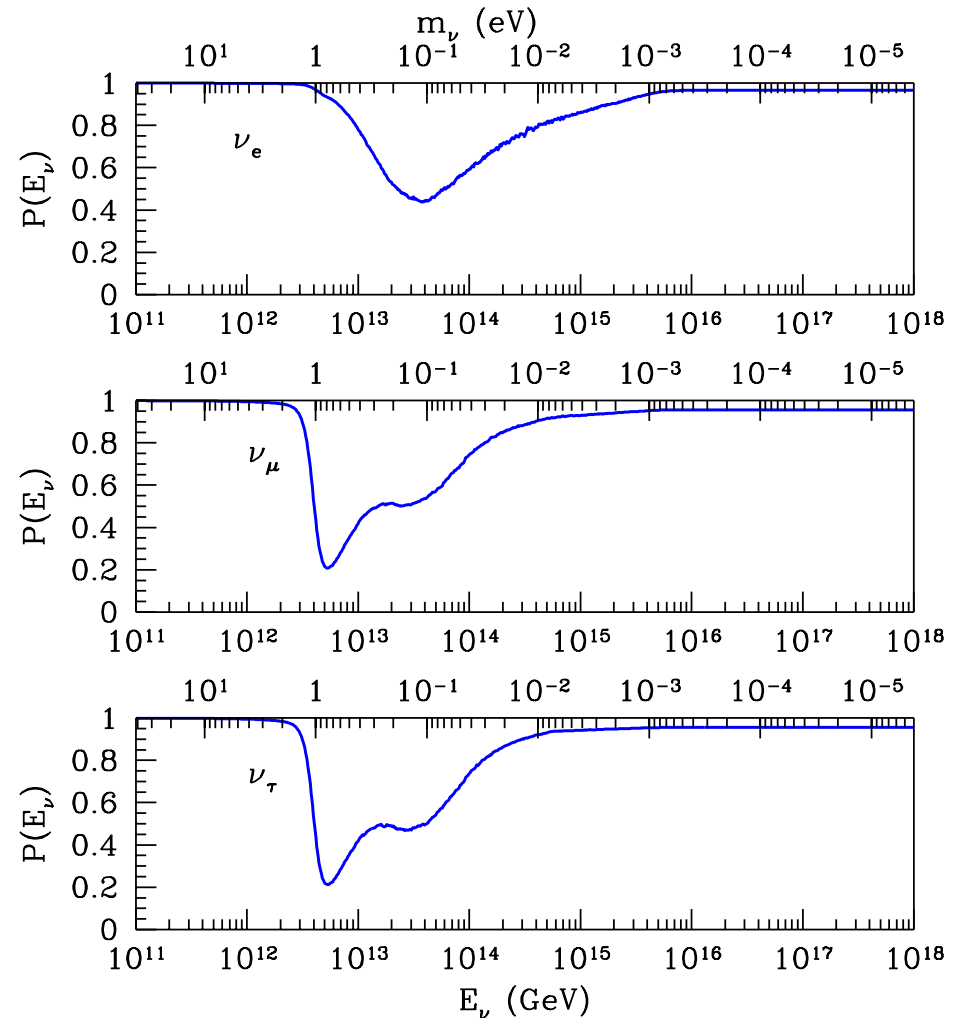
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[Barenboim, Mena, Quigg '05]

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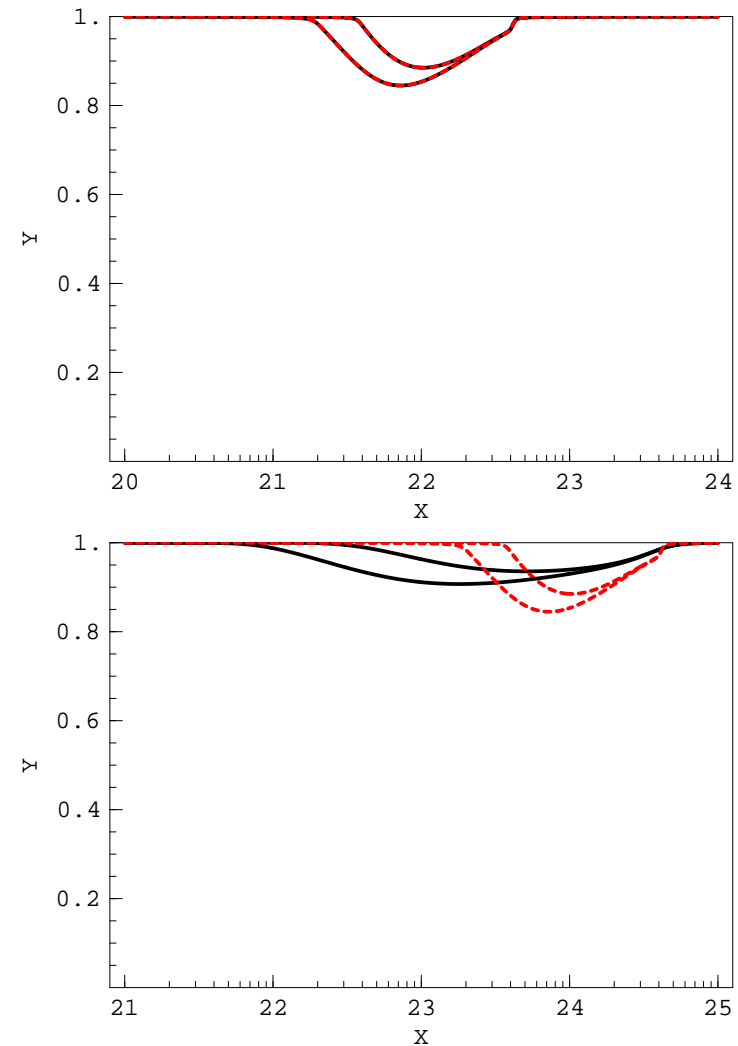
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[D'Olivo,Nellen,Sahu, Van Elewyck '05]

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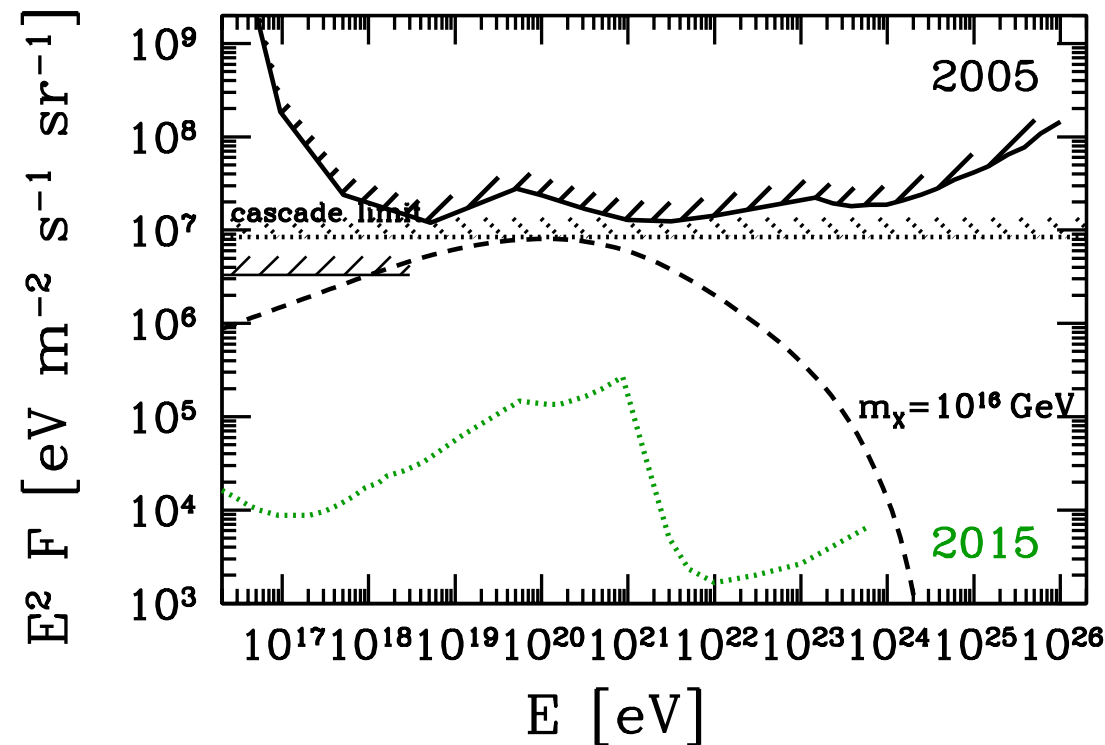
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⇒ Absorption dips in super-GZK neutrino spectra

- Detectable within next decade if
 - $m_X \gtrsim 10^{15} \text{ GeV}$
 - super-GZK neutrino flux close to current observational bounds



[Eberle, AR, Weiler, Wong, in prep.]

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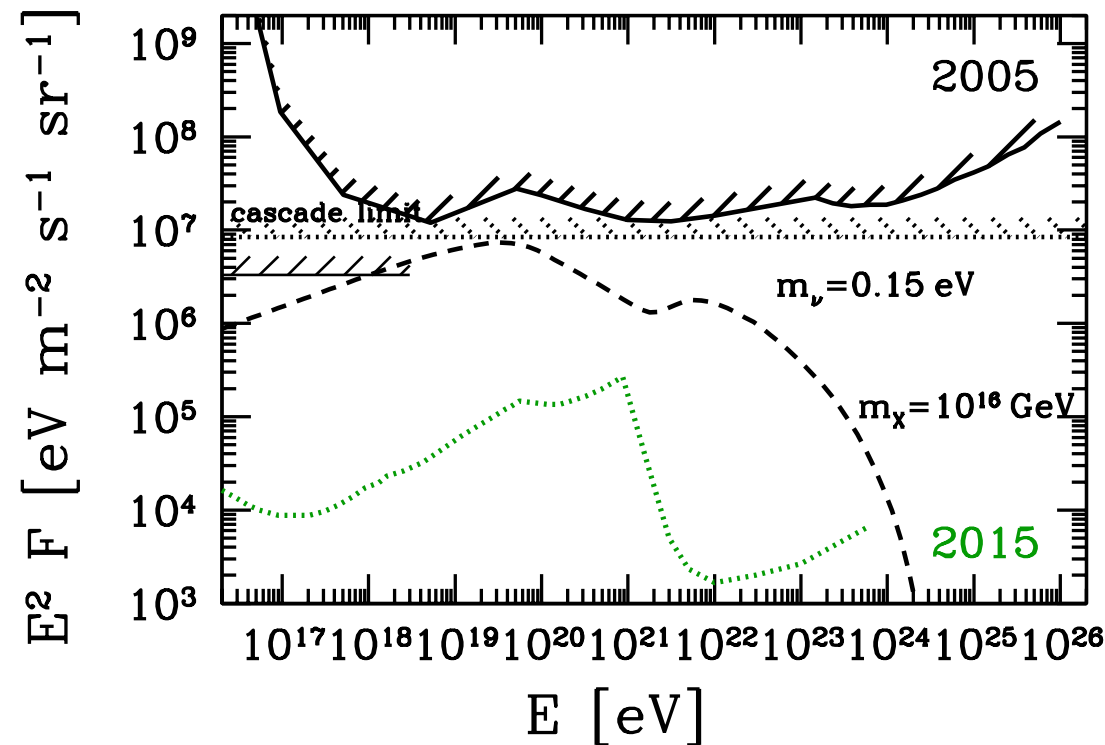
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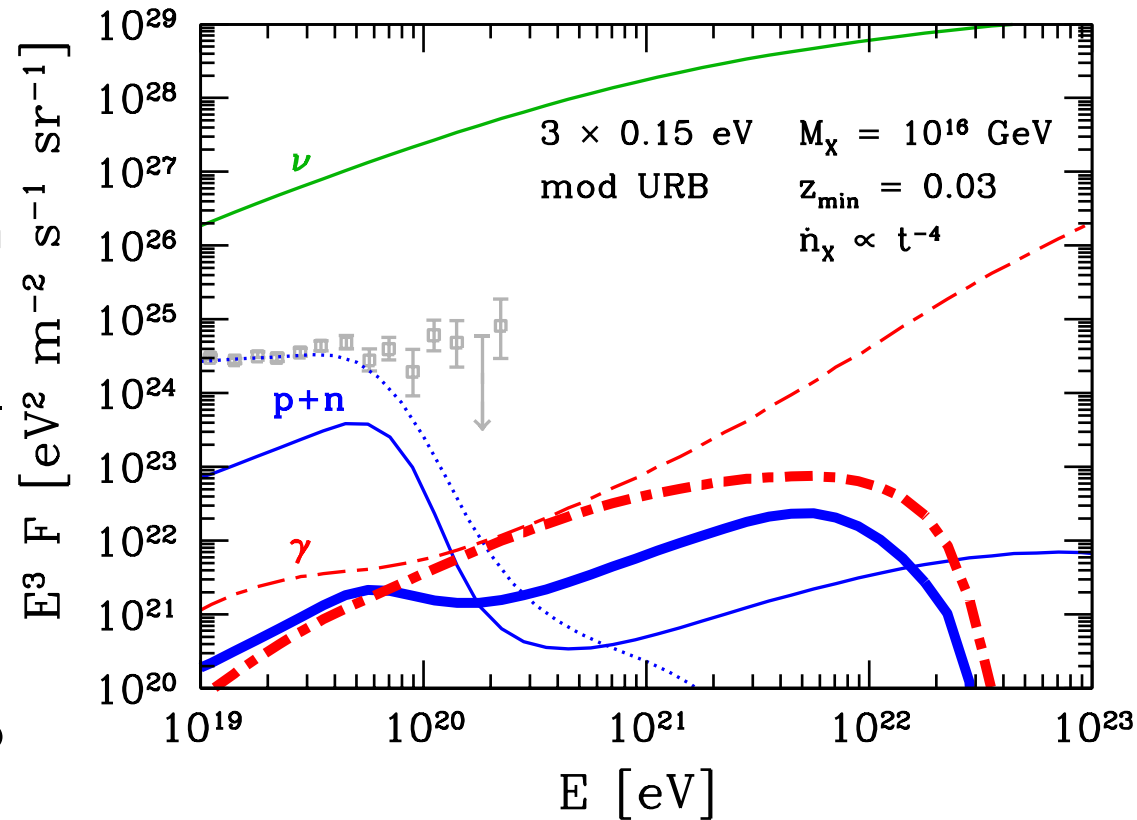
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- Z -bursts as super-GZK recovery



[Eberle,AR,Weiler,Wong,in prep.]

4. Conclusions

- Exciting times for super-GZK neutrinos:
 - many observatories under construction
 - ⇒ appreciable event samples
- Expect strong impact on
 - astrophysics
 - particle physics
 - cosmology

